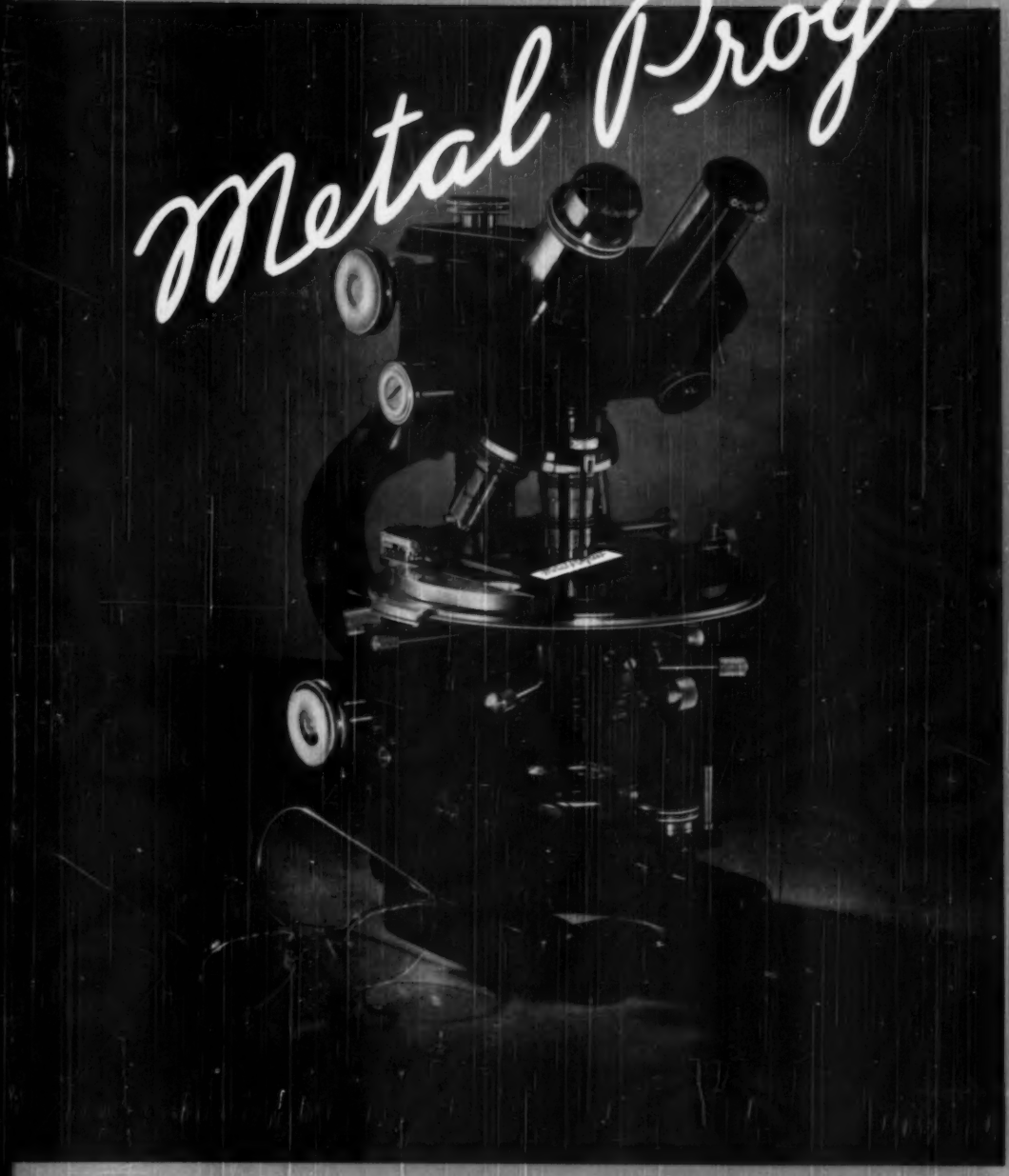
# Metal Progress



January 1950

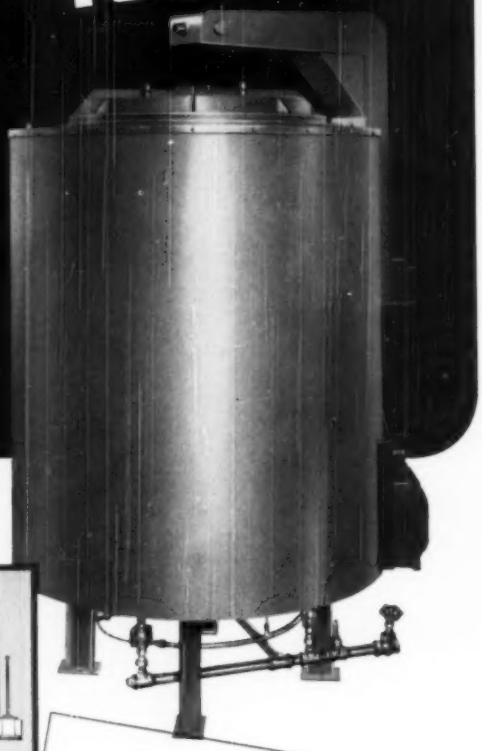
**ADVANCED**
**COMBUSTION SYSTEM**
**NEW**
**MUFFLE DESIGN**

Combined in the Revolutionary, New

*'Surface'*

# Atmotrol

## VERTICAL MUFFLE FURNACE

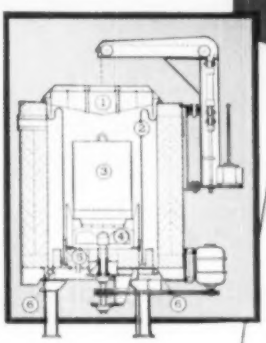


● All modern heat treatments including clean hardening, without scale or decarburization, gas carburizing and dry (gas) cyaniding of steel parts are accomplished in the gas-tight, heat-resisting alloy muffle.

The 'Surface' Two Stage Multiple Injection Burner equipment does not require air under pressure and provides uniform temperature distribution throughout the muffle heating chamber. Maximum heating efficiency is assured.

The hydraulically operated top cover facilitates the vertical lift type of work handling which is popular in modern materials handling systems for industrial plants.

The Atmotrol Furnace is ideal for small parts heat treatment. Work is loaded in a basket through which the atmosphere gases are recirculated by a high capacity fan.



1 *Hydraulically Operated Lift Cover*
2 *Gas Tight Vertical Alloy Muffle*
3 *Materials Charge Basket*
4 *High Capacity Fan*
5 *Atmosphere Gas Inlet*
6 *Two-Stage, Multiple Injection Burners*

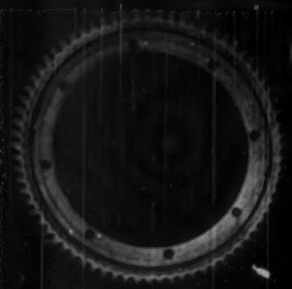
**FREE!**
**COMPLETE FURNACE DATA**
*Write for Specification MV-49*

'Surface'

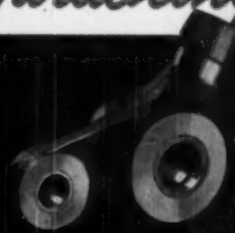
SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

**STANDARD RATED FURNACES AND INDUSTRIAL BURNERS**

## Hardening



Production up from 14 to 35 per hour, and savings of $82,507 per year on this International Harvester gear.



Over 4¢ saved on every part, 600 parts per hour when Lima-Hamilton TOCCO-hardens these shifting levers.

Hardening costs cut 80% by TOCCO-hardening wearing area of Link Belt Company conveyor trolley wheels.

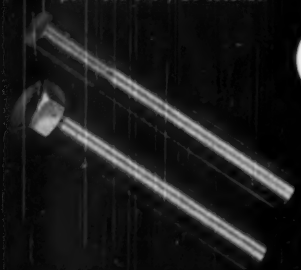
## Brazing

Kennametal, Inc. brazes carbide tips on these mining machine bits and hardens shanks at the same time. Output—one every 20 seconds.

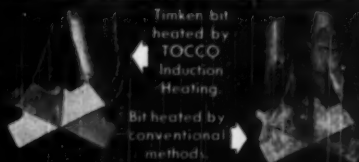
Nash Motors cuts cost 60%, triples hourly output by TOCCO-brazing drain flanges to automotive oil pans.

A 6¢ TOCCO-brazing job saves $17.00 tools—saves $2,000 a month at a midwest automotive parts plant.

## Forging



H. M. Harper boosts production up to 265% and die life up to 400% by TOCCO-heating non-ferrous bolt blanks for forging.




Scale was reduced from 2.79% to 79% by applying TOCCO to heating bar stock for forging rock drill bits at Timken Roller Bearing Company.

Forging die life tripled and scale reduced over 99% when Willy's Overland Commercial Forge Plant installed TOCCO Induction Heating for forging.

***All These Jobs, And Probably Some of Yours, Can Be Done Faster, Better and at Lower Cost with TOCCO* Induction Heating***

**THE OHIO CRANKSHAFT COMPANY**

**TOCCO**

*Mail Coupon Today*

NEW FREE BULLETIN

**THE OHIO CRANKSHAFT CO.**
**Dept. R-1, Cleveland 1, Ohio**

Please send copy of "TOCCO Induction Heating".

Name _____

Position _____

Company _____

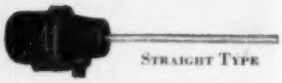
Address _____

City _____ Zone ____ State _____

# THE HOTTEST NEWS IN FLAME SAFETY

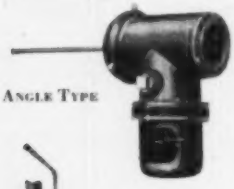
. . . . .

. . THE ALL-NEW PROTECTOGLO!



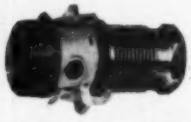
STRAIGHT TYPE

FLAME-ELECTRODE RECTIFIERS *for non-luminous gas*



ANGLE TYPE

FLAME-RECTIFIER PILOT—*a combined flame-electrode rectifier and gas pilot burner assembly*



PHOTOCELL RECTIFIER *—is ideal detector unit for use with luminous flames*

**AND there are a lot of good reasons why the all-new Protectoglo is receiving such an enthusiastic reception. In addition to the versatility demonstrated by the availability of the four different flame detector units pictured above, the new Protectoglo boasts these outstanding features:**

- *Automatic Self-Checking, without manual push-button, provides "Safe-Start" Circuit and safeguards against component failure.*
- *Positive Flame Failure Protection through the* rectification principle *which eliminates unsafe conditions due to grounding . . . does not rely on flame conductivity or resistance.*
- *Expensive shielded cable not required.*
- *Plug-In Timer is optional for purge timing.*
- *Relite is possible without additional relays.*

BROWN INSTRUMENTS — WORLD'S LARGEST ORGANIZATION FOR ADVANCED INSTRUMENTATION AND CONTROL

Call in your local Honeywell engineer for detailed information . . . or write for a copy of Specification Sheet 526.

*The All-New Protectoglo Is Now Available For Immediate Delivery!*

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
4503 Wayne Ave., Philadelphia 44, Pa.
Offices in 73 principal cities of the United States, Canada and throughout the world

Honeywell — *Advanced Instrumentation* FOR METAL PROCESSING — Honeywell

# TOOLING UP? You save three ways when you harden the Vapocarb-Hump way

IN tooling up for new products . . . or retooling for present models . . . there's often opportunity to make significant savings, simply by improving the heat-treatment of necessary punches, dies, and other tools. For the heat-treatment — the strength-giving process in tooling-up — largely determines the value of all tool designing and machining which have gone before.

A tool like the one above, for example, is worth at least $150 when it reaches the heat-treat, for at that point it represents a hundred pounds of high-grade steel plus several days of painstaking effort and irreplaceable labor. It's up to the heat-treater to help meet production time-tables and assure that this previous investment results in a tool which will give maximum service.

With a Vapocarb-Hump furnace for hardening . . . and a Homo furnace for tempering . . . a competent heat-treater will give you the full results to which his skill and experience entitle you.

**1. Little or no refinishing . . . because tool surface is protected by Vapocarb atmosphere control.**

**2. No rejections . . . because tool shape and size are "as expected" under rate of heating control.**

**3. Long tool life . . . because correct internal structure can be produced through Hump control of quench point.**

• • •

He'll make any tool — whether a massive die, an insert, or a tiny slitting edge — perform to maximum ability. He'll make your heat-treat a steady source of triple savings . . . savings which reach back into the toolroom — and forward into production departments.

Ask an L&N engineer to explain the Vapocarb-Hump — and Homo Methods. Or, if you prefer, we'll send our catalog. Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl Ad T-620(28)

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Entrance end of giant Lindberg brazing furnace, showing Inconel furnace tray in loading position. Furnace was assembled and tested in the Lindberg shop (right) before delivery.

# LINDBERG BUILDS WORLD'S LARGEST BRAZING FURNACES

## Furnace trays are INCONEL for maximum service in temperatures up to 2100° F.

The Lindberg Engineering Company of Chicago recently built what is thought to be the world's largest brazing installation.

The equipment consists of two huge brazing furnaces and a large annealing furnace.

The brazing furnaces are each 190 ft. overall length. The operating temperature is 2100° F. Each furnace is supplied with 120 *Inconel** trays measuring 28 in. by 42 in., and weighing 47 pounds each.

The annealing furnace is 118 ft. long. Operating temperature is 2100° F. 35 *Inconel* trays and baskets were supplied with the furnace. Trays are 28 in. by 42 in. with 3 in. deep wire mesh baskets. Tray weight is 32 pounds; basket weight about 15 pounds.

Like other leading furnace manufacturers, Lindberg chose *Inconel* as the furnace tray material because of its excellent service record in severe high-heat applications.

*Inconel* offers a combination of high thermal durability and excellent high temperature oxidation-resistance. It is workable and weldable. Your INCO distributor has *Inconel* readily available in all standard mill forms and sizes.

The Lindberg Engineering Company will be glad to answer your inquiries concerning furnace and heat-treating equipment. Address: 2450 W. Hubbard St., Chicago 12, Ill.

If you would like additional information about *Inconel* . . . and help with your high-temperature equipment problems, write directly to INCO.

**THE INTERNATIONAL NICKEL COMPANY, INC.**
**47 Wall Street, New York 5, N. Y.**

*Reg. U. S. Pat. Off.

EMBLEM OF SERVICE INCO

**INCONEL*. . . for long life at high temperatures**

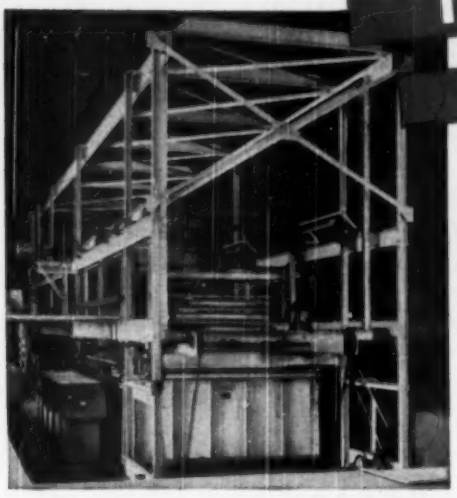
# FINISH-MACHINE PARTS *before* YOU HEAT TREAT THEM!

## It's entirely practical

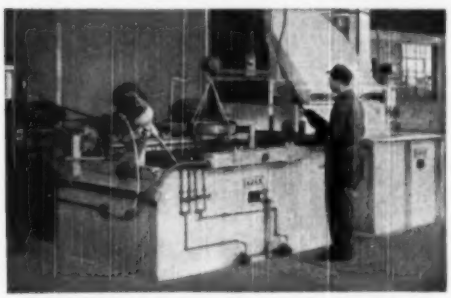
**BY MARTEMPERING OR AUSTEMPERING IN AJAX SALT BATHS**

## It's a lot cheaper

## It speeds production



Automobile bumpers are austempered in mass production in this Ajax mechanized unit. Fast salt bath heating cycle saved $\frac{2}{3}$ floor space required by radiant heating unit.



Martempering bearing races (through-hardened to 57-61 RC.) in salt baths eliminated die quenching equipment and reduced distortion. Savings in final grinding operation alone quickly repaid investment.

Make a really worthwhile saving by eliminating expensive finishing on treated parts!

The development of the Ajax Isothermal Heat Treat Process for martempering, austempering and other interrupted quenching operations has replaced the conventional quench and temper method in hundreds of installations because of its ability to deliver uniformly heat treated parts remarkably free from distortion. The range of products being treated include dies, gears, tools, bearing races, crankshafts, blades, automobile bumpers, springs, revolver parts, cutlery, business machine parts, piston rings, cast iron cylinder sleeves, wrenches, agricultural implements, etc. Besides the benefits resulting from greatly reduced distortion, Ajax furnace users profit from the following additional advantages:

*ELIMINATION OF QUENCH CRACKS*
*PREVENTION OF SCALING AND DECARB*
*INCREASED TOUGHNESS AND DUCTILITY*
*REDUCED FLOOR SPACE*
*FASTER HANDLING WITH LESS LABOR*
*ADAPTED TO MECHANIZATION*

Write for Ajax Isothermal Bulletin 120. Better yet, let us treat a batch of your specimen parts under actual working conditions in the Ajax Metallurgical Service Laboratory. See for yourself the outstanding advantages of this method.

**AJAX ELECTRIC COMPANY, INC.**
**910 Frankford Avenue • Philadelphia 23, Penna.**

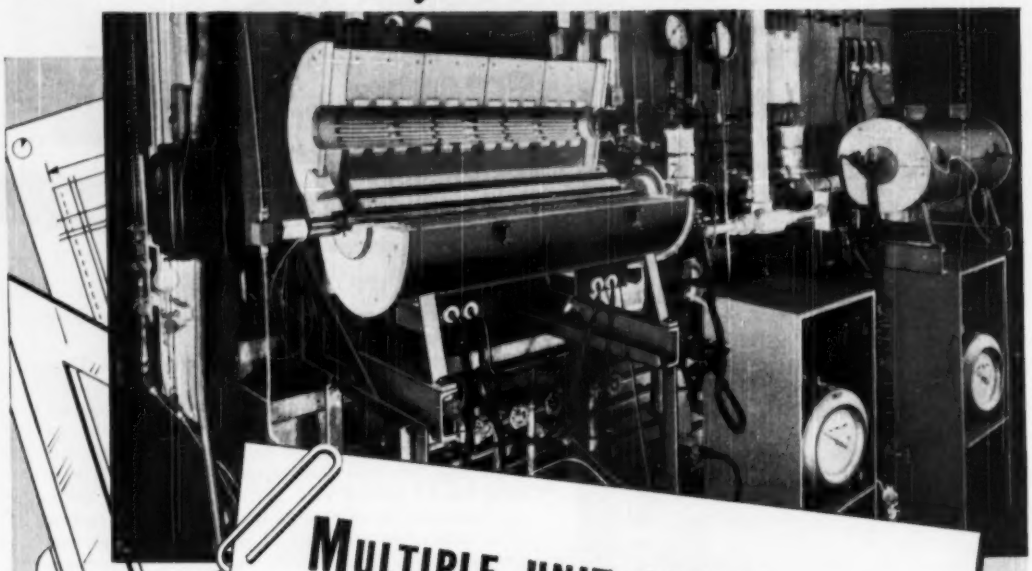
**The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively!**

*ASSOCIATED COMPANIES:*
AJAX METAL CO. AJAX ELECTRIC FURNACE CORP.
AJAX ELECTROTHERMIC CORP. AJAX ENGINEERING CORP.

*IN CANADA:*
Canadian General Electric Co., Ltd., Toronto, Ontario

**AJAX HULTGREN ELECTRIC SALT BATH FURNACES**

# "Equipment of rugged design *and capable of close experimental control has been developed for these needs."*



## MULTIPLE UNIT COMBUSTION TUBE FURNACES

Multiple Unit Combustion Tube Furnaces are standard in most laboratories. With the concentrated search for better materials and improved processes, these furnaces are proving their value over and over again because of their ability to give close experimental control.

As a typical example, the two Type M-3024 Furnaces shown were used in the laboratory of one of the world's large petroleum development companies by H. J. Henriques in his "Evaluation of vapor phase reactions with solid catalysts." ++ (Ind. Eng. Chem. 39, 1564, 1947).

For complete details concerning Multiple Unit Combustion Tube Furnaces, see your laboratory supply dealer or write for Bulletin HD-1236.

**HEVI DUTY ELECTRIC COMPANY**

LABORATORY FURNACES **MULTIPLE UNIT** ELECTRIC EXCLUSIVELY

TRADE MARK REG. U. S. PAT. OFF.

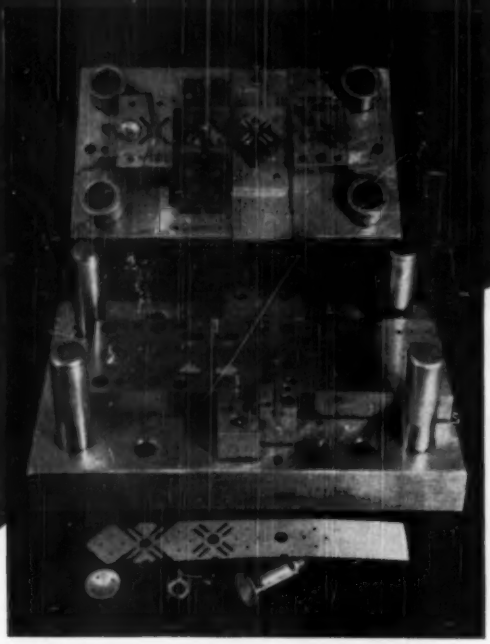
**MILWAUKEE 1, WISCONSIN**

# A-H5

## (5 PCT CHROME AIR-HARDENING)

## *A Toolroom Favorite on 5 counts*

1. Air-hardening for safety.
2. Good wear-resistance.
3. Good toughness.
4. Excellent resistance to deformation.
5. Easy to machine.

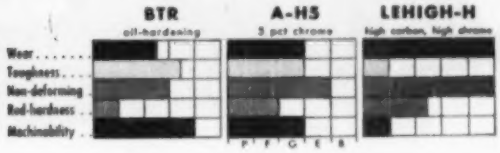


*"A-H5 always meets or exceeds our expectations . . ."*

This comment comes from the chief engineer of Day and Night Division, Affiliated Gas Equipment, Inc., in Monrovia, California. This company makes a modern line of gas, space and water heaters for home and commercial uses. The die shown is used to pierce, blank and form burner canopies from .0235-in. stainless-steel strip. With all its parts made of A-H5 except the punches (they are Lehigh H), this progressive die is still going strong after producing several hundred thousand pieces, samples of which are shown in the foreground.

There's plenty of versatility in this 5 pct chrome, air-hardening tool steel. And it's economical, too, often replacing more expensive grades.

A-H5 is a general-purpose steel that fits in between the standard oil-hardening steels (such as Bethlehem's BTR) and the high-carbon, high-chrome tool steels like Lehigh H (another Bethlehem champion). Here's a quick comparison of the properties of all three:




(Poor, Fair, Good, Excellent, Best)

Use A-H5 for a variety of dies, punches, blanking tools, cold-forming dies, master tools, gages, and the like. Give it a thorough trial and you'll be sold on having it in your toolroom to stay. Let the nearest Bethlehem sales office or tool-steel distributor give you complete information. Quick delivery from our mill depot or local distributor's stock.

### HEAT-TREATMENT OF A-H5

| | C | Mn | Cr | Mo | V |
|---|---|---|---|---|---|
| Typical Analysis: | 1.00 | 0.60 | 5.25 | 1.10 | 0.25 |

Annealing: Pack, heat to 1650 F, slow furnace-cool, Brinell 212 max

Preheating: 1200 to 1250 F, prior to hardening

Hardening: 1775 F, air-quench

Tempering: 350 to 400 F, Rockwell C 60 to 62

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

*Export Distributor:*
Bethlehem Steel Export Corporation

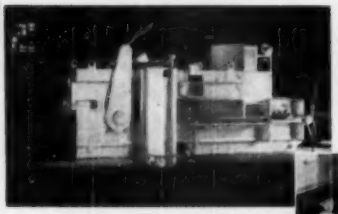
BETHLEHEM STEEL

SUPERSONIC TESTED

# Bethlehem Tool Steel

# *Controlled*

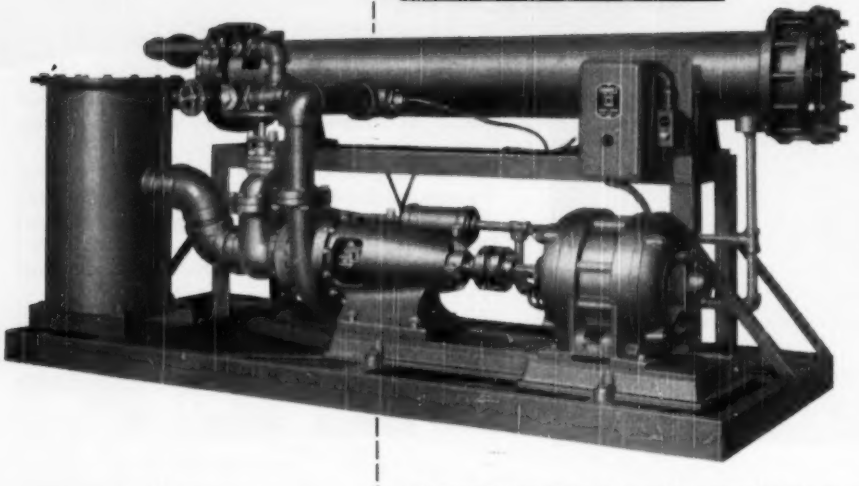
# Quenching... Expertly Engineered

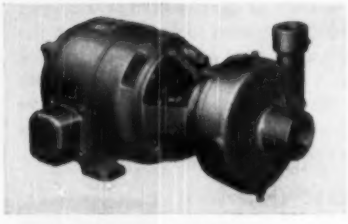


**WE SURVEY...** A B & G representative, in consultation with your engineers, examines your plant layout and determines what results are desired in your heat treating department.

**WE ENGINEER...** From data accumulated in your plant, the B & G engineering staff designs a complete quench-oil system, tailored to your specific requirements.

**YOU RECEIVE...** A complete recommendation as to size and type of equipment needed is delivered to you promptly. The only remaining step is to install the equipment.





**B&G SERIES 1522 PUMP**
One unit of a complete line of centrifugal pumps—catalog on request.

The quenching stage of your heat-treating process is the point where all previous operations are brought to either a successful or unsatisfactory conclusion.

At this point is determined the *final* quality of your product . . . the amount of time and material wasted by sub-standard rejects . . . and *your ultimate operating cost!*

When you install a B & G *Hydro-Flo* Oil Quenching System you are assured of uniform quality because *identical conditions* are maintained through every moment of the quench period. Positive circulation and proper turbulence of the oil maintains the desired temperature in all parts of the quench tank.

Write today for descriptive literature on B&G *Hydro-Flo* Quench Oil Coolers.

**Hydro-Flo® OIL QUENCHING SYSTEMS**

**BELL & GOSSETT COMPANY**

**Dept. BH-16, Morton Grove, Ill.**

®Reg. U. S. Pat. Off.

*Heat-treating equipment since 1916*

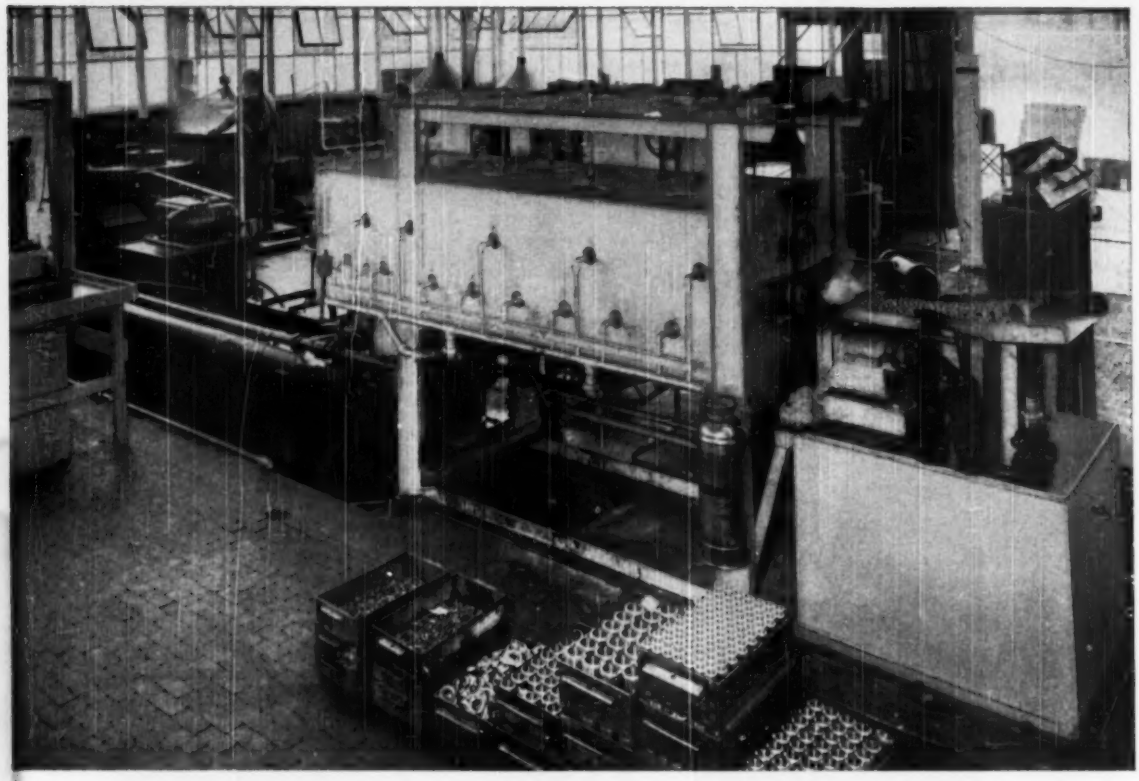
Stainless steel works miracles only when the *right* type is matched to the right application. Crucible, a pioneer in the development of stainless steels, offers the services of our unsurpassed metallurgical staff to help you make the right choice.

And Crucible produces a complete range of sheet and strip in gauges, grades and finishes from 1/2" to 60" inclusive, as well as all other forms: plates, bars, tubing, forgings, wire and castings to meet your specific requirements. Data sheets are available on request. CRUCIBLE STEEL COMPANY OF AMERICA, Chrysler Building, New York 17, New York.

**CRUCIBLE** first name in special purpose steels

hot and cold rolled **STAINLESS SHEET AND STRIP**

STAINLESS • HIGH SPEED • TOOL • ALLOY • MACHINERY • SPECIAL PURPOSE • STEELS



The neat and compact installation illustrated above is that of our No. 166 Reciprocating Furnace with Automatic Quench Tank as installed at the Jacobs Manufacturing Company plant for the case hardening and clean hardening of various parts. One of the reasons this furnace was selected in place of a cyanide bath, the method previously employed, was that it eliminated the difficult cleaning job on threaded parts such as chuck jaws, chuck nuts, etc.

# *A. G. F.* RECIPROCATING FURNACES FOR PRODUCTION HEAT TREATING

The following are but a few of their many desirable features:

VERSATILE. Each furnace can be used without modification to process work ranging from extremely small, light springs, stampings, and drop forgings, etc., up to quite large and heavy pieces.

POSITIVE ATMOSPHERE CONTROL. The full muffle type Reciprocating Furnace has been redesigned to provide a 100% atmosphere seal.

SIMPLE. There is no complicated drive mechanism or conveyor belt maintenance problem. Only the work, advancing through the muffle by its own momentum, enters and leaves the furnace.

ECONOMICAL. Increased production per man-hour, long alloy life, and minimized maintenance produce a lower heat treating cost per unit of work treated.

**WRITE TODAY FOR BULLETIN 815-AB**

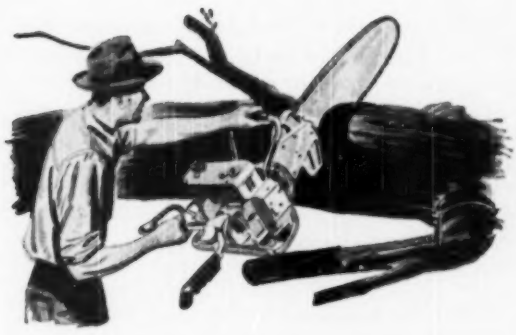
## AMERICAN GAS FURNACE CO.

**1002 LAFAYETTE STREET ★ ELIZABETH 4, N. J.**

# Greater ease in use accompanies products made lighter with . . . Dow

# MAGNESIUM

## the world's lightest structural metal!



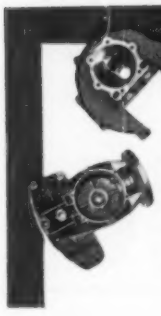
If your product is designed to save manpower, one metal—Magnesium—deserves your first consideration.

*Magnesium is the world's lightest structural metal.* It gives portable tools new found lightness because it is a full one-third lighter than any other light metal. Saws, hand tools and countless other products become easier to lift and move—easier to sell—with magnesium. And this bonus—this premium of lightness—is yours without sacrificing needed strength and durability, because parts made from magnesium are sturdy and long lasting.

Give your product the vital selling advantage of noticeably greater ease in use—switch to magnesium. Write for a free copy of "How Magnesium Pays," a book filled with actual case studies of successful magnesium applications.

**THE DOW CHEMICAL COMPANY • MIDLAND, MICHIGAN**

New York • Boston • Philadelphia • Washington • Atlanta
Cleveland • Detroit • Chicago • St. Louis • Houston • San Francisco
Los Angeles • Seattle
Dow Chemical of Canada, Limited, Toronto, Canada



### *Cut Dead Weight And Production Costs, Too . . . With Magnesium Die Castings*

Magnesium die castings are the obvious choice for portable equipment. They enable designers to save pounds and dollars at the same time. Magnesium die castings are as strong as they are light. And they can be cast to extremely close tolerances which eliminates much costly machining.

***Lighter Products Sell—make your product Magnesium Light***

*Announcing*

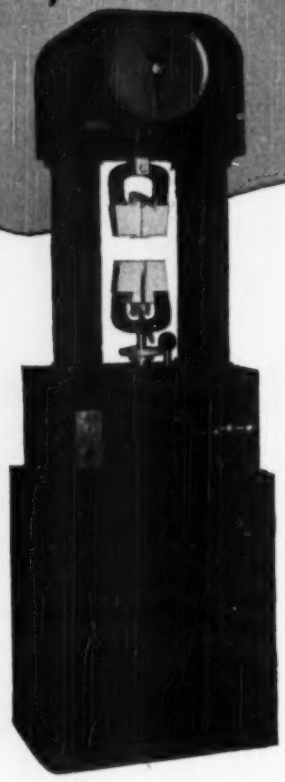
# THE NEW OLSEN LC UNIVERSAL TESTING MACHINE

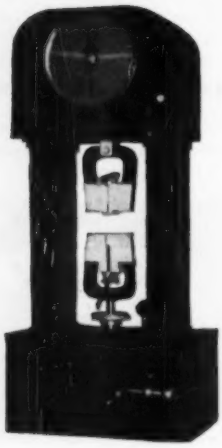
*(Guaranteed to meet ASTM, Army, Navy, and Federal Specs.)*

TINIUS OLSEN

**Low Cost**

TESTING MACHINES





## *Built for Small Budgets without sacrifice of quality*

**Again Olsen provides the answer—the new LC testing machine is ideal for industrial production and quality control, laboratory, educational, and shop testing of metals, wood products, ceramics, textiles, insulating materials, wire, plastics, and many other materials.**

**Dual capacity ranges of 10,000 lbs. and 1,000 lbs. are provided for standard tensile compression, and transverse testing of metals; standard and special tools are available for testing other materials.**

**The LC is produced in both hand operated and motor operated models, both of which are priced to fit the tight budget.**

**The new LC is a modern, compact, dependable testing machine with extreme versatility built to the exacting requirements of all testing equipment produced by Tinius Olsen Testing Machine Company. Write today for Bulletin 41.—**

TINIUS OLSEN

*Testing & Balancing Machines*

TINIUS OLSEN
TESTING MACHINE CO.
2030 Easton Rd., Willow Grove, Pa.

## It just LOOKS easy

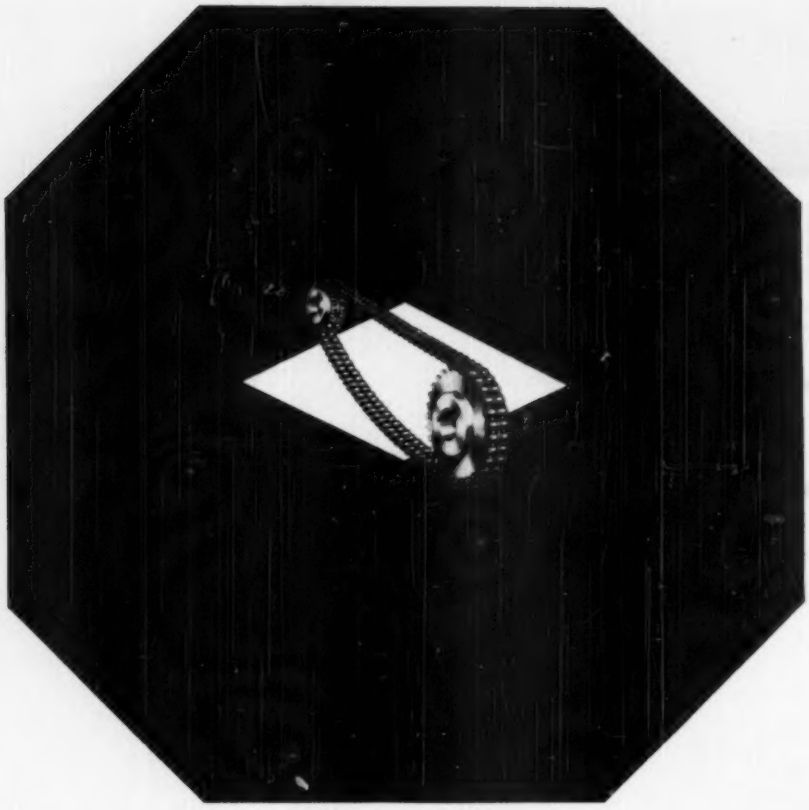
That ski jump is smooth and looks simple but appearances deceive. It's the product of practice to develop skill, precision and timing.

Making fine steel also demands skill, precision and timing. Here at Wisconsin Steel through metallurgical control, we exercise the greatest care in producing every heat of steel.

Our product is made for an exacting clientele—our customers. It must meet their specifications. Find out about Wisconsin Steel *Quality Products* by contacting our sales and metallurgical staffs. They are ready to serve you.

**WISCONSIN STEEL COMPANY, Affiliate of INTERNATIONAL HARVESTER COMPANY**
180 North Michigan Avenue • Chicago 1, Illinois

# WISCONSIN STEEL



# Diamond Roller Chains Acknowledge Their Debt to the AMERICAN SOCIETY FOR METALS

Roller chains make greater demands on the quality of the metals used in their manufacture than do most mechanical products.

Constant research on the behavior of metals under stress, careful study of the mechanism of heat treatment, painstaking control of the melting and rolling practices are required to provide metals which satisfy the needs of Diamond Roller Chains. Better metal parts are developed by carefully trained metallurgical engineers on our own staff and in the organizations of our suppliers.

These men are sincerely devoted to their profession, are willing to share the record of their successes with others and are eager to apply the advances of other fields of science to the solution of their problems.

The American Society for Metals provides a medium for the interchange of knowledge and experience. Thus it is contributing vitally to the continued improvement of Diamond Roller Chain.

DIAMOND CHAIN COMPANY, INC.
Dept. 604, 402 Kentucky Avenue, Indianapolis 7, Indiana

# NEW LA-LED®

## FREE MACHINING SCREW STOCK

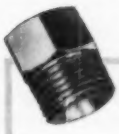
## Lead-Bearing Open-Hearth Steel MACHINES TWICE AS FAST AS B-1112

***PRODUCTION INCREASED 45% to over 100%***

***When LASALLE LA-LED Replaces B-1113***

In LA-LED, LaSalle is now furnishing a new cold-finished, lead-bearing open-hearth steel which has been proven not only by tests but by actual production runs to be the fastest machining steel available. Added to its superlative machinability, LA-LED has the desirable qualities only an open-hearth steel can offer: it will carburize better, and has a much sounder cross section than Bessemer steels; its good ductility permits bending, crimping, and riveting operations often impracticable with the free machining screw steels; and it machines to a fine satiny finish. LA-LED is available for quick delivery in rounds 5/16" through 1¾"; in hexagons 5/16" through 1½". Larger sections—up to 3" round and 2½" hexagon—available in mill quantities. Investigate today—LA-LED can save *you* money.

**Improved Finish— BETTER Crimping and Riveting Properties**



**COMPARATIVE RESULTS**

**% Change LA-LED over B-1113**

**PART: TUBE NUT**

| *MADE FROM:* ⅝" Hexagon Cold-Finished Steel Bars | | | *MACHINED ON:* 1" New Britain 6-Spindle Automatic | |
|---|---|---|---|---|
| Form Tool | RPM | +71% | Drill Feed | +15% |
| Form Tool | SFM | +75% | Time Per Part | −42% |
| Form Tool | Feed | + 4% | Increase in production | +72% |
| Drill | SFM | +71% | Increase in steel cost | +13% |

LaSalle Steel Co.
1424 150th Street
Hammond, Indiana

Please give me more information on how LA-LED can increase production and cut the cost of screw machine parts in my shop.

Name_____

Title_____

Company_____

Address_____

City_____ State_____

*LaSalle* **STEEL COMPANY**

**Manufacturers of the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Bars in America**

# Aluminum does them all—but...

Naturally, you don't make pots and airplanes with the same alloy.

To manufacture the products illustrated above, a *variety* of alloys and tempers of aluminum are required—each suited to the specific requirements of the job.

How about *your* product? Does it fully utilize aluminum's advantages?

A change in alloy or temper may enable you to *improve your product* by giving it:

**Increased strength . . . reduced weight . . . improved finish . . . greater durability.**

Furthermore, by making a change in alloy or temper you may be able to *reduce your manufacturing costs* through:

**Lower material cost . . . fewer fabricating steps . . . lower rejection rate . . . lower finishing costs.**

Sometimes a minor change in product design—which would enable you to make use of a different alloy—will result in one or more of these benefits.

So ask yourself if you're taking fullest advantage of aluminum's remarkable versatility. If there's any doubt, call in a Kaiser Aluminum engineer and he'll give you the answer!

Kaiser Aluminum is produced by Kaiser Aluminum & Chemical Corporation.

**Kaiser Aluminum**

SOLD BY KAISER ALUMINUM & CHEMICAL SALES, INC., KAISER BUILDING, OAKLAND 12, CALIFORNIA . . . OFFICES IN: Atlanta • Boston • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • Houston • Indianapolis • Kansas City • Los Angeles Milwaukee • Minneapolis • New York • Oakland • Philadelphia • Portland, Ore. • Rochester, N. Y. • Seattle • Spokane • St. Louis Wichita • EXPORT OFFICE, OAKLAND, CALIFORNIA • WAREHOUSE DISTRIBUTORS IN PRINCIPAL CITIES

This is no idle promise. It is a proved fact, demonstrated day after day in the production of widely varied parts and products. Three tons of N-A-X HIGH-TENSILE are yielding as many finished units as were previously yielded by *four* tons of carbon sheet steel.

This "new arithmetic in steel" is helping scores of manufacturers. They are taking advantage of N-A-X HIGH-TENSILE'S greater strength and corrosion-resistance to reduce sections an average of 25%—and still provide greater strength and durability than can be obtained with thicker sections of mild-carbon steel.

At a time when America must make full use of its steel-producing capacities and conserve its natural resources, the trend to N-A-X HIGH-TENSILE has national significance. Each ton produced represents a potential 33% increase in finished goods of superior quality. Investigate the opportunity to make each ton of sheet steel go farther—through the superior quality of N-A-X HIGH-TENSILE.

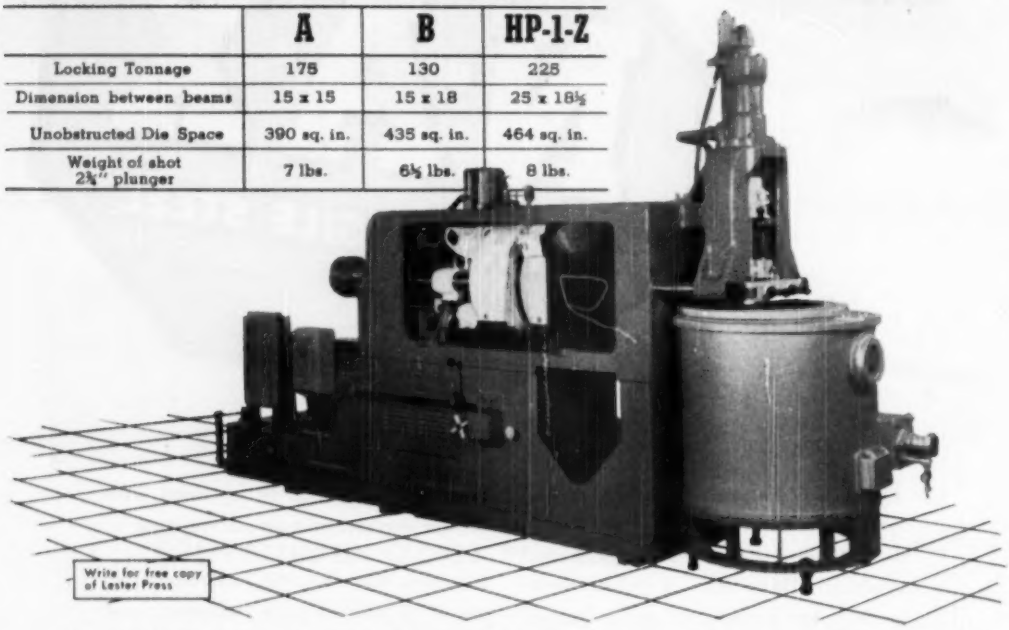
# GREAT LAKES STEEL CORPORATION

**N-A-X ALLOY DIVISION • ECORSE • DETROIT 29, MICHIGAN • UNIT OF NATIONAL STEEL CORPORATION**

# ZINC DIE CASTING?
# LESTER-PHOENIX?
# YES! *and low priced too!*

**COMPARE THESE BASIC SPECIFICATIONS . . .**

| | A | B | HP-1-Z |
|---|---|---|---|
| Locking Tonnage | 175 | 130 | 225 |
| Dimension between beams | 15 x 15 | 15 x 18 | 25 x 18½ |
| Unobstructed Die Space | 390 sq. in. | 435 sq. in. | 464 sq. in. |
| Weight of shot 2¾" plunger | 7 lbs. | 6½ lbs. | 8 lbs. |




The new HP-1-Z was designed for zinc die casters. Compare the specification—the HP-1-Z is outstanding in comparison to any machine of like size—and still retains all the famous Lester features: solid frame, large central adjusting screw, interlocking safety features, and extremely rapid production of quality pieces. • Besides all this, you get the latest development—the new, easy-to-set-up, easy-to-maintain zinc end with the big melting pot.

It's the machine designed for *your* needs—write for complete specifications.

## *LESTER-PHOENIX DIE CASTING MACHINES*

**REPRESENTATIVES**

New York . . . . . Steven F. Krould
Chicago . Elmer C. Maywald & Co., Inc.
Detroit . . . . . .Tharesen-McCash
Cincinnati . . . . Index Machinery Corp.
Milwaukee . . Marquette Engineering Co.
Los Angeles . . .Seaboard Machinery Co.
New England . . . .Kavanagh Sales, Inc.
Cleveland . . . . . Don W. Williams
San Francisco . . . . . .J. Fraser Rae
Philadelphia . .Wright & Gade Tool Co.

**FOREIGN**

Toronto, Canada Modern Tool Works, Ltd.
London, England . . Dowding & Doll, Ltd.
Calcutta, India . . . Frances Klein & Co.
Sydney, Australia . .Scott & Holladay, Ltd.
Japan, New York . . W. M. Hewitt, Inc.

*distributed by* LESTER-PHOENIX, INC., 2619 CHURCH AVENUE • CLEVELAND 13, OHIO

# Cyanide Disposal Problems Minimized

**S-M-O-O-T-H PLATING.**
The fine-grained Unichrome deposit gives smoothness without the need for brighteners.

**BUFFING TIME IS CUT.**
If needed at all, buffing of the ductile, free-flowing copper takes little time, less effort.

**ANODES CORRODE EVENLY.**
Unichrome bath needs fewer anodes to maintain copper in solution. It keeps anodes clean and efficient.

**EASILY CONTROLLED.**
Unichrome Copper is stable bath, does not build up carbonate, has good tolerance for impurities.

**ONE BATH FOR ALL JOBS.**
It plates zinc die castings, aluminum, intricate shapes; provides suitable undercoat for nickel, chromium; stops-off for nitriding, carburizing.

**by the**

## UNICHROME Pyrophosphate Copper Plating Bath

Many localities already prohibit unregulated disposal of plating room wastes. More and more are taking steps to control dumping of solutions and rinse waters. Cyanide-bearing wastes such as those from cyanide copper baths are particularly critical – due to their toxicity even when greatly diluted.

Solving the cyanide disposal problem by installing a treating unit is expensive. The more cyanide you have, the greater is the expense. You can minimize this expense by using the non-cyanide Unichrome Pyrophosphate Copper plating bath, which not only is safer, but also offers outstanding advantages in operation such as those described at the left.

If you want *complete* details, showing how the Unichrome Pyrophosphate Copper plating bath can help you do a better, safer finishing job at lower cost, write us for informative literature. Or better yet, ask us to have an engineer discuss this matter with you.

UNICHROME

Trade Mark Reg. U.S. Pat. Off.

**PROCESSES AND MATERIALS FOR SURFACES THAT SURVIVE**

**UNITED CHROMIUM, INCORPORATED**

51 East 42nd St., New York 17, N. Y. • Ferndale Sta., Detroit 20, Mich.
Chicago 4, Ill. • Waterbury 90, Conn. • Los Angeles 13, Cal.

# Sunbeam STEWART

**THE BEST INDUSTRIAL FURNACES MADE**

Regardless of whether you heat treat in small quantities or continuous production, Sunbeam Stewart engineers are well qualified to recommend the correct furnaces to meet your requirements.

As a division of Sunbeam Corporation we have the opportunity of working with our furnaces in the production of Sunbeam appliances, lawn sprinklers, sheep shears, animal clippers, etc. In manufacturing our own products we must contend with practically every heat treating problem faced by industry—a position unique in the furnace manufacturing field.

This experience with our own furnaces in both small or large volume production enables us to render a service to you far beyond other manufacturers. That is one reason why Sunbeam Stewart Furnace installations have been so successful. They are based not only on furnace engineering ability, but on practical experience under actual operating conditions. We have learned through actual experience the factors that give longest furnace life . . . greatest production . . . best quality . . . and lowest operating cost.

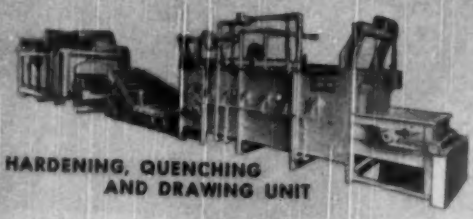
Our highly trained technical staff of furnace engineers, who for over 50 years have built furnaces for the leading companies throughout the United States and abroad, are qualified to recommend the correct type of furnace to meet your requirements.

*A letter, wire or 'phone call will promptly bring you information and details on Sunbeam Stewart Furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a Sunbeam Stewart engineer will be glad to call and discuss your heat treating problem.*

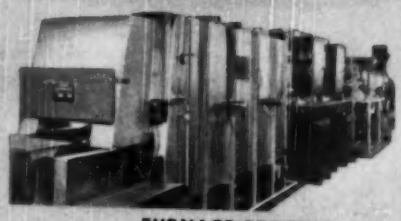
**THERE IS A SUNBEAM STEWART INDUSTRIAL FURNACE FOR EVERY NEED**

**GAS · ELECTRIC · OIL**

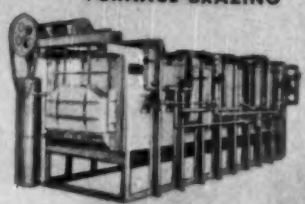
GALVANIZING



HARDENING, QUENCHING AND DRAWING UNIT



FURNACE BRAZING



PORTABLE OVEN FURNACE

**FREE Vest-Pocket Heat Treating Data Book. MAIL today. CHECK for information on furnaces to meet your needs.**

- ☐ Atmosphere-controlled
- ☐ Bonderizing
- ☐ Brazing furnace
- ☐ Car bottom
- ☐ Case hardening
- ☐ Combination
- ☐ Complete toolroom
- ☐ Continuous production heat treat line
- ☐ Electric high speed
- ☐ Electric pre-heat
- ☐ Forging
- ☐ Galvanizing
- ☐ Gas carburizing
- ☐ Gas nitriding
- ☐ High speed steel
- ☐ Metal melting
- ☐ Oven
- ☐ Pot
- ☐ Recirculating
- ☐ Rivet heaters
- ☐ Rotary hearth forge
- ☐ Soldering iron heaters
- ☐ Tempering
- ☐ Tool hardening

NAME _____ TITLE _____

COMPANY _____

ADDRESS _____ CITY _____ STATE _____

RECIRCULATING FURNACES

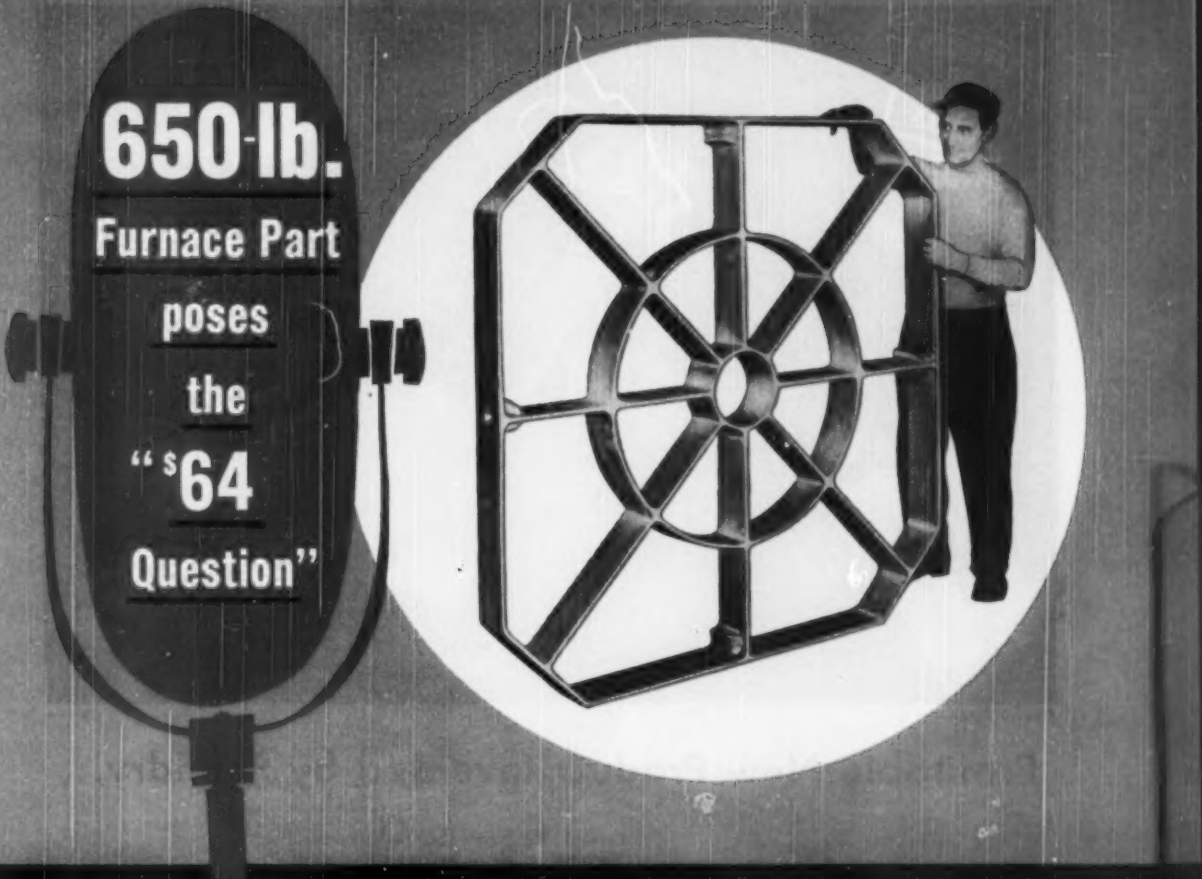
**SUNBEAM STEWART INDUSTRIAL FURNACE DIVISION of SUNBEAM CORPORATION**

(Formerly CHICAGO FLEXIBLE SHAFT CO.)

Main Office: Dept. 108, 4433 Ogden Ave., Chicago 23—New York Office: 322 W. 48th St., New York 19—Detroit Office: 3049 E. Grand Blvd., Detroit 2

Canada Factory: 321 Weston Rd., So., Toronto 9

# 650-lb. Furnace Part poses the "$64 Question"



When Wright Aeronautical Corporation decided to install a large roller batch furnace for heat-treating turbo-jet engine assemblies and other parts, the furnace base plate presented unusual manufacturing difficulties.

Required to provide a surface area of more than 30 square feet, it had to be as light as possible, yet capable of delivering a long life of dependable service, without distortion, at operating temperatures of 1700° - 1800° F.

Final specifications called for a base plate of intricate shape, cast in Nichrome . . . because Nichrome is superlatively resistant to heat and corrosion at high temperatures.

Since nickel-chrome alloys have a high rate of shrinkage, however, actual production of the base plate called for exceptional foundry know-how. Only the most precise compensations and controls could prevent a casting of this shape and size from being ruptured completely in the mold—at as many as 24 different places.

Here, at Driver-Harris, we produced this 650-lb. furnace part without flaw—another example of the outstanding ability of our foundries to take care of tough jobs!

We have had more than 36 years' experience designing, fabricating and casting furnace parts and fixtures, and as makers of world-famous Nichrome*, Chromax* and Cimet*, we are prepared to help solve YOUR heat-treating problems with equipment unsurpassed for dependability, efficiency and economy.

FIFTIETH ANNIVERSARY — SPECIAL PURPOSE ALLOYS SINCE 1890 — D/H — REGD. U.S. PAT. OFF.

Nichrome, Chromax and Cimet are manufactured only by

## *Driver-Harris Company*

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

* T. M. Reg. U. S. Pat. Off.

*Photo by Toby Chadwick* JMLco F131

# Profitable New Product Invented by Foundry...

A sound idea, engineering skill, and the *right* Federated metals for its cast components are combined in the LITTCO ELECTRIC MOWER, manufactured by the Littlestown Hardware and Foundry Company, Inc., Littlestown, Pa.

Competent design and liberal use of castings made of Federated aluminum alloys have resulted in the production of a 24 lb. electric lawn mower which, although it requires only one hand to operate, will cut grass up to 15 inches high with no trouble.

Eighteen parts of the mower, including the sides, the housing, wheels, back rollers and brackets, are cast of Federated TENZALOY and Federated F-720, the former being used where extra high strength is demanded.

TENZALOY is produced only by Federated Metals. It is an aluminum alloy which gives high strength without heat treatment, as-cast strengths reaching 30,000 psi., and still higher with 10-14 days aging at room temperature.

For TENZALOY . . . for any non-ferrous alloy, including aluminum, magnesium and copper-base foundry metals; solders; bearing metals; and fabricated lead products . . . see Federated first.

Federated first in the non-ferrous field AMD

Federated METALS DIVISION

AMERICAN SMELTING AND REFINING COMPANY, 120 BROADWAY, NEW YORK 5, N.Y.

# Since 1917

The first Spencer Turbo was installed in 1917. Many of the early machines are still in service. A few of the equipment manufacturers that have used Spencers consistently (see dates) for many years are represented on this page.

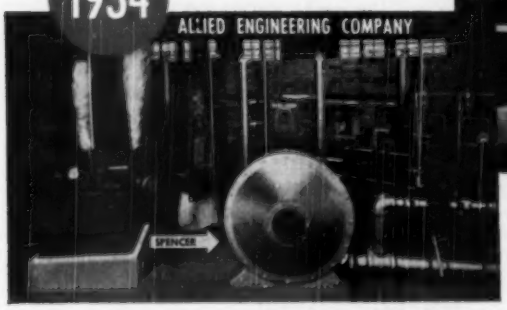
1921

1939

1929

1925

1934




Standard sizes from 35 to 20,000 cu. ft.; ½ to 800 H.P.; 8 oz. to 10lbs. Single or multi-stage, two or four bearing. Special gas-tight and non-corrosive construction available.

Special Spencer Bulletins are available as follows: Data, No. 107, Gas Boosters, No. 109, Four Bearing, No. 110, Blast Gates, No. 122, Foundries, No. 112 and the General Bulletin is No. 126.

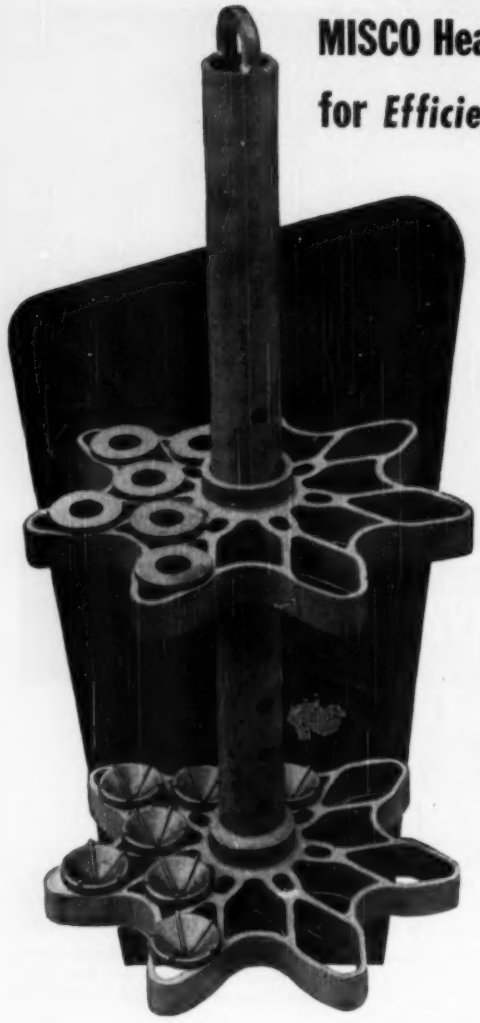
359-F

SPENCER HARTFORD

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONN.

# TURBO-COMPRESSORS

# MISCO HEAT RESISTING ALLOYS



## MISCO Heat Treating Equipment is Designed for *Efficiency* and Built for *Endurance* . . .

**We illustrate a typical Misco Fixture for carburizing and quenching. This adjustable fixture is 22″ overall diameter x 48″ high and carries 14 shafts weighing 40 pounds each at 1700°F. Total applied load is 560 pounds. The weight of the fixture complete with bushings and supporting cones is 190 pounds. The weight ratio of work treated to that of construction is almost 3:1. We can always provide the best design to do your work efficiently and economically. Let us build maximum endurance into YOUR equipment.**

## *Specify* MISCO HEAT RESISTING ALLOYS

• *CAST AND ROLLED* •

### for your Heat Treating Equipment

FURNACE PARTS • ROLLER RAILS • ROLLER HEARTHS • CONVEYOR ROLLS • TRAYS • RETORTS • CHAIN • MUFFLES • WALKING BEAM CONVEYORS • CARBURIZING AND ANNEALING BOXES • DIPPING BASKETS • CYANIDE AND LEAD POTS • THERMOCOUPLE PROTECTION TUBES • PICKLING EQUIPMENT • CENTRIFUGAL CASTINGS • PRECISION CASTINGS • MISCELLANEOUS CASTINGS AND ROLLED BARS • SHEETS, PLATES, TUBES AND WELDING ROD FOR USE AT HIGH TEMPERATURE OR UNDER CORROSIVE CONDITIONS.

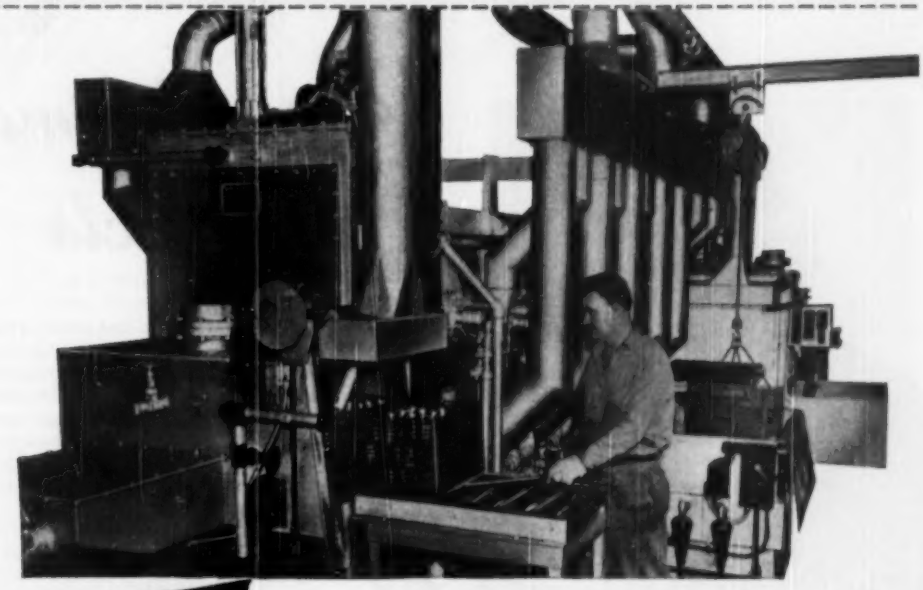
**ALLOY CASTING DIVISION**
**Michigan Steel Casting Company**

MISCO
Heat and Corrosion Resistant Alloys

*One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys*

**1998 GUOIN STREET • DETROIT 7, MICHIGAN**

YOU CAN BE SURE.. IF IT'S
Westinghouse



FOR THE MAN WHO CAN'T BE SOLD

**Here's the solution to your Gas Carburizing Problems**

Westinghouse Therm-a-neering has the answers. This engineering and metallurgical service is offered with no obligation to the man who "can't be sold", but, who is willing to accept *proof* of efficiency and dependability. Therm-a-neering custom-builds equipment to fit your individual requirements, assuring smooth and economical operation of your heat-treating line.

Take the carburizing furnace shown above, for example: one continuous and complete operation puts all parts through the same cycle, same atmosphere, same temperature. Uniformity of parts is assured. Rejects are eliminated.

And the work is done fast. No handling of parts is required between charging and discharging. Doors open automatically. One operator handles all work easily. Production is maintained at 800 net pounds per hour.

This installation is typical of the way Westinghouse furnaces—both gas-fired and electric—are answering today's production problems. And because Westinghouse engineers have no favorite to play, they can study your problems from an unbiased point of view in helping you select the equipment to do your job most efficiently and economically.

Let Therm-a-neering help you. Call your nearby Westinghouse representative for details, or write Westinghouse Electric Corporation, 181 Mercer St., Meadville, Pa. J-10350

*Therm-a-neering.* A HEAT AND METALLURGICAL SERVICE THAT OFFERS WITHOUT OBLIGATION:

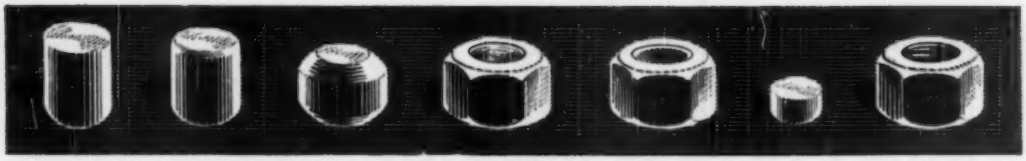
**ENGINEERS**—Thermal, design and metallurgical engineers to help you study your heat-treating problems with a view toward recommending specific heat-treating furnaces and atmospheres.

**RESEARCH**—A well-equipped metallurgical laboratory in which to run test samples to demonstrate the finish, hardness and metallurgical results that can be expected on a production basis.

**PRODUCTION**—A modern plant devoted entirely to industrial heating.

**EXPERIENCE**—Manufacturers of a wide variety of furnaces—both gas and electric—and protective atmosphere generators.

Westinghouse
GAS AND ELECTRIC
Furnaces



# For Minimum Rejects

FROM first to last, nuts formed from Youngstown Scrapless Nut Quality Wire stand strict inspection--by magnetic particle or the usual visual inspection methods. That's because Youngstown Scrapless Nut Quality Wire comes to you so free from piping, seams, laps, die marks, internal tearing and cupping and nonmetallic inclusions.

Available in various compositions including AISI standard as well as special sulphurized steels.---Cold heading bolt wire, of comparable quality, in all standard carbon analyses available for prompt shipment to the bolt and nut industry.

# Youngstown

## SCRAPLESS NUT QUALITY WIRE

**THE YOUNGSTOWN SHEET AND TUBE COMPANY** General Offices Youngstown 1, Ohio

*Manufacturers of Carbon, Alloy and Yoloy Steel* Export Office-500 Fifth Avenue, New York

WIRE · ELECTROLYTIC TIN PLATE · COKE TIN PLATE · PIPE AND TUBULAR PRODUCTS · HOT AND COLD FINISHED CARBON AND ALLOY BARS · RODS · SHEETS · PLATES · CONDUIT · RAILROAD TRACK SPIKES

# AJAX-NORTHRUP MELTING HITS COMPOSITION

# "Right on the Nose"

And every heat of today's high-performance alloys *must* be checked out "right on the nose." The slightest oxidation or contamination means rejected castings—or loss of time and alloying constituents trying to bring the melt up to par.

That's why more and more foundries, alloy steel plants, and precision casting shops are turning to Ajax-Northrup melting as the only practical, economical way.

Ajax-Northrup high frequency furnaces stir as they melt — electrically. There's no carbon to contaminate the charge. One user holds carbon content within two one-hundredths of one per cent. It's so fast there's no oxidation. Savings in constituents and deoxidizers alone give Ajax-Northrup furnaces a two-to-one cost advantage in a nickel-steel plant. Melts fast or slow, or holds steady temperature. Easy to charge, requires little attention while melting.

## 33 YEARS OF EXPERIENCE

By combining the right work-proven Ajax-Northrup units with the right controls, we can tailor high frequency melting to your requirements. Motor-generator power from 25 to 1200 kw. and up. Self-tuning, trouble-free spark-gap converters from 3 to 40 kw. Furnaces from one ounce to a ton for all non-ferrous, and precious metals—to 8 tons for ferrous metals. Just name your alloys and quantities—we'll send you the proper technical bulletins—free.

STEEL

BRASS AND BRONZE

ALLOY CAST IRON

PRECISION CASTING

## AJAX ELECTROTHERMIC CORPORATION

AJAX PARK, TRENTON 5, N. J.

SINCE 1916

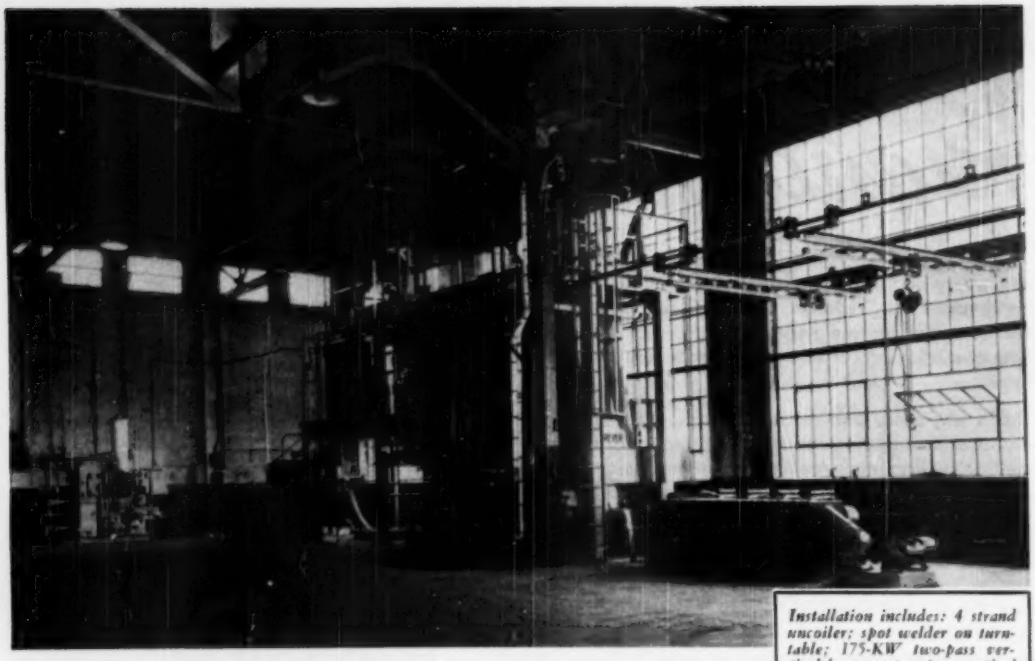
AJAX NORTHRUP

HEATING & MELTING

117

*Associate Companies*

THE AJAX METAL COMPANY • AJAX ELECTRIC FURNACE CORPORATION
AJAX ELECTRIC COMPANY, INC. • AJAX ENGINEERING CORPORATION



*Installation includes: 4 strand uncoiler; spot welder on turntable; 175-KW two-pass vertical furnace; two-pass vertical cooling tower; multi-chamber pickling tank; drying unit; master pinch roll; 4-head recoiler; complete hi-nitrogen atmosphere equipment.*

# DREVER CONTINUOUS VERTICAL STRIP ANNEALING LINE

**WATERBURY ROLLING MILLS, INC., WATERBURY, CONN.**

Clean, bright or matte finish brass or nickel-silver strip is being annealed continuously in this installation which handles an average production of 2000#/hour of two 12″ strands or four 6″ strands .030″ thick. Max. strand width 13″; min. width 2″; max. thickness .060″; min. thickness .008″.

Non-explosive reducing atmosphere contains low percentages of CO and $H_2$ with practically no traces of $CO_2$ and moisture.

The multi-chamber pickling tank in the line produces die-saving matte finish, or may be by-passed when bright finish is required.

We will be pleased to furnish data obtained from this and other continuous strip lines for comparison with your present annealing practice.

**DREVER CO.**

790 E. VENANGO ST., PHILA. 34, PENNA.

CONTINUOUS FURNACE LINES, HEAT TREATING FURNACES, DESCALING & ATMOSPHERE EQUIPMENT

NEW YORK & NEW ENGLAND—GERALD B. DUFF, 68 CLINTON AVE., NEWARK 5, N. J.
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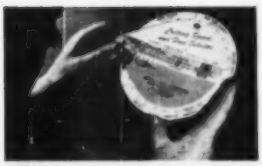
# *a Fountain Favorite...*

There's no compromise with quality when it comes to protecting the taste and purity of America's favorite soft drinks. That's why sanitary, easy-to-clean, corrosion-resistant ENDURO Stainless Steel (Type 303) is used for these fountain dispenser valve parts.

From a manufacturing standpoint, there are other reasons, too, for the specification of ENDURO Cold Finished Bars. Close tolerances . . . accuracy of section . . . uniform soundness . . . fine surface finish . . . and UNIFORMLY HIGH MACHINABILITY . . . all combine to keep down unit costs and reject losses.

Whenever you need top machinability plus one or more of the other qualities which only stainless steel can provide, remember to specify Republic ENDURO Stainless Steel Bars—cold finished or hot rolled—and wire. Available for prompt delivery. Write us *today*.



**A VALUABLE AID FOR MACHINISTS**

It's a handy Speed and Feed Selector to help you in machining stainless steel. Send for one TODAY. . it's FREE.

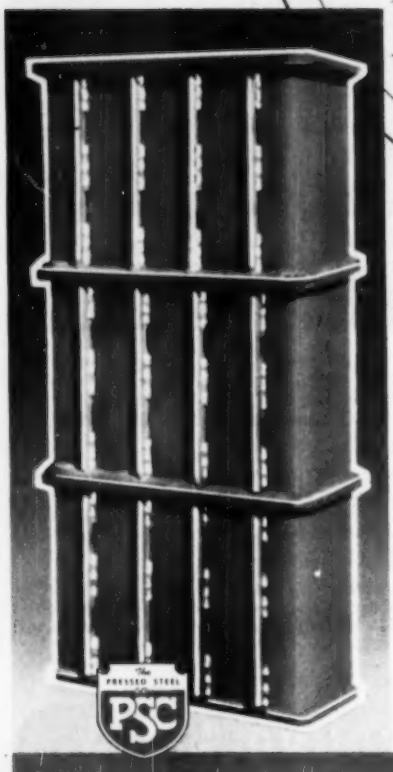
**REPUBLIC STEEL CORPORATION**
ADV. DIVISION • DEPT. MP
3100 East 45th Street
Cleveland 4, Ohio

Republic ENDURO FREE-MACHINING STAINLESS STEEL

REPUBLIC STEEL

Other Republic Products include Carbon and Alloy Steels—Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

# THESE BOXES
# *Shortened Furnace Cycle*
# 5 HOURS




## *Another "PSC" Production Saving*

The PSC annealing box at left is another example of how we are helping our customers in these days of mounting competition. This 3-tier unit for continuous malleablizing (no bottom in center box) cut 5 hours from one customer's furnace cycle, due to its 2/3 lighter weight and faster handling. For another customer these much less bulky units increased furnace capacity and eliminated the need of enlarging their heat-treating department. Another installation so substantially increased operating efficiency that all 34 furnaces in the plant were equipped.

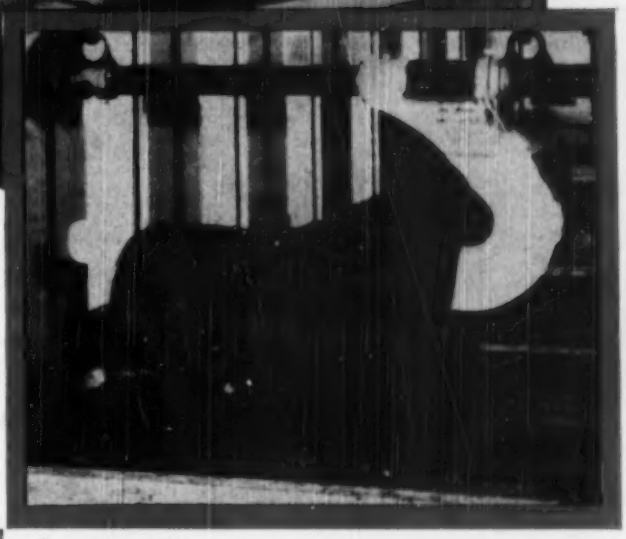
As pioneers of light-weight sheet alloy heat-treating containers and covers, Pressed Steel Co. furnishes units for every product — in any size, design or metal specification. Let us help you cut costs. Send blue prints or write as to your needs.

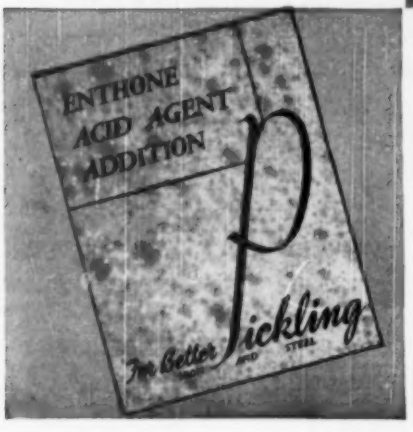
**THE PRESSED STEEL COMPANY**
of WILKES-BARRE, PENNSYLVANIA

*Industrial Equipment of Heat and Corrosion Resistant* WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

*THESE Before and After pictures* show the results you can obtain by using Enthone Acid Addition Agent. The health of the worker is safeguarded, corrosion on surrounding buildings and finished steel is reduced, and an acid drag-out saving of twenty percent is obtained.






*Send for this informative bulletin giving step-by-step details for better pickling*

*OTHER AIDS FOR BETTER PICKLING*

*Inhibitor 7 C* – a low-priced, complete inhibitor for hydrochloric acid.

*Inhibitor 9* – a new type of inhibitor for hydrochloric, sulphuric, hydrofluoric or other non-oxidizing acids. A complete inhibitor that is free-rinsing and leaves the metals bright.

**ENTHONE INC.**

**442 ELM STREET, NEW HAVEN, CONNECTICUT**

Advertisement

# ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

# CHROMIUM...key metal for strength, corrosion resistance, and heat resistance

Chromium is one of the most important alloying elements in iron and steel metallurgy since it markedly improves certain chemical and physical properties.

## Increases Strength

The strength of steels is greatly increased by chromium because it retards the transformation of certain constituents during rapid cooling.

This makes it possible to obtain great depth of hardness in high-carbon steels, toughness in structural steel, and high strength and ductility in heavy sections. Chromium also increases resistance to shock by refining the grain of the steel.

Of all the alloying elements, chromium is probably the least expensive for increasing the tensile strength of steel. Additions of as little as 0.25 to 1.25 per cent chromium will increase the chill and hardness

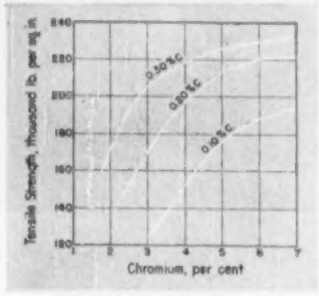



*Fig. 1. Chromium increases the tensile strength of air-cooled steels of varying carbon content.*

of the steel, as well as the tensile strength.

In copper, aluminum, and other nonferrous alloys, chromium provides increased strength, also.

## Imparts Corrosion Resistance

Commercially, chromium is added to steel and iron in amounts up to 30 per cent for the purpose of improving corrosion resistance.

In general, as the chromium content is increased with a given carbon content, the resistance of the steel to corrosive media becomes greater. The well-known "stainless" steels resist corrosion because substantial percentages (usually 12 per cent or more) of chromium are present.

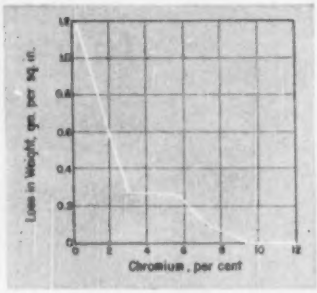



*Fig. 2. Results of atmospheric corrosion tests on low-carbon steels of different chromium contents after 10 years of exposure to an industrial atmosphere.*

## Improves Heat Resistance

In both cast iron and steel, chromium provides good resistance to deterioration from heat. The use of chromium-alloyed iron and steel where high temperatures are encountered, for example, helps to prevent oxidation, which would ruin equipment. As little as 1 to 2 per cent chromium is added to cast iron to improve oxidation resistance and reduce growth of grate bars subject to high temperatures. Oxidation resistance improves progressively as the chromium is increased. Steels containing as little as 5 per cent chromium show good life at temperatures up to 1200 deg. F. For higher temperatures, appropriate steels of higher chromium content may be selected. Steels containing 25 to 28 per cent chromium give satisfactory service at temperatures up to 2100 deg. F.

Alloy cast irons with 15 to 30 per cent chromium are commonly used for applications requiring resistance to severe heat and abrasion.

In non-ferrous alloys, also, chromium is an important constituent for heat and corrosion resistance. It is used in the production of non-ferrous metal-cutting tools, chromium bronzes, and electrical resistance alloys.

## Available Alloys

Chromium is produced by ELECTROMET in the forms listed below which are suitable for every use of the iron, steel, and nonferrous metal industry.

"CMSZ," "EM," "Electromet," and "SM" are trademarks of Union Carbide and Carbon Corporation.

## Alloys of Chromium and Their Uses

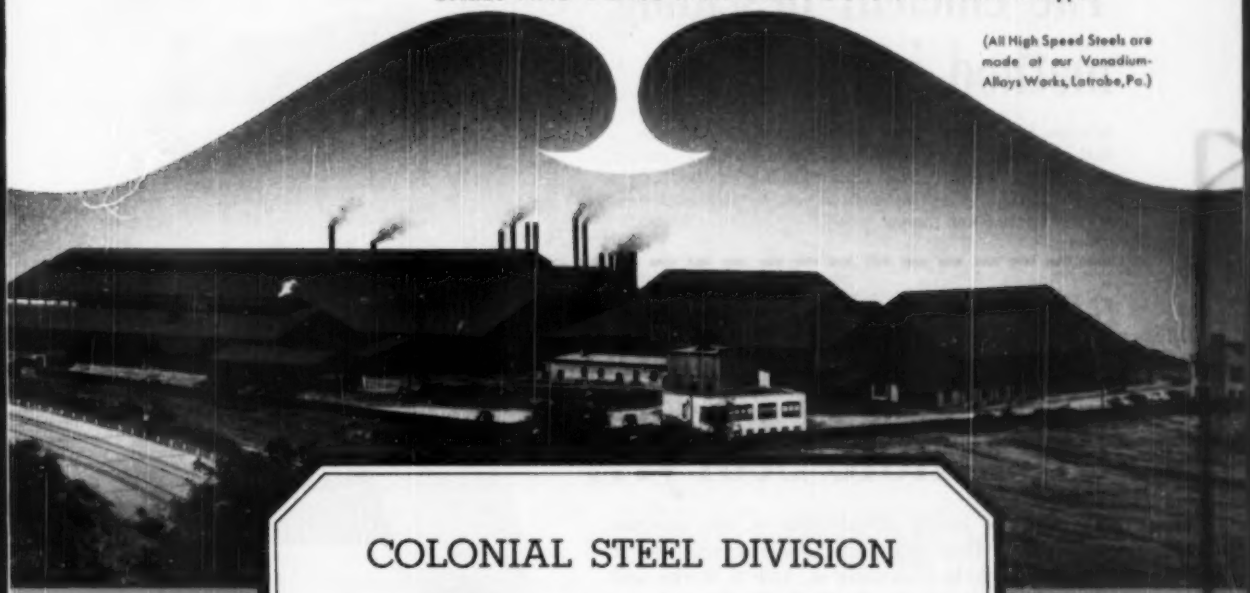
| | |
|---|---|
| **Low-Carbon Ferrochrome** | For production of corrosion- and heat-resistant steels, commonly known as the "stainless steels," as well as special high-temperature alloys in which a low carbon content is desirable. |
| **High-Carbon Ferrochrome** | For production of chromium-bearing steels that do not require low percentages of carbon. Also used for adding chromium to cast iron. |
| **Nitrogen-Bearing Ferrochrome** | For reducing grain size and improving physical properties of high-chromium steels. |
| **Ferrochrome-Silicon** | Used in the production of stainless steels for adding chromium to the bath, and for reducing oxidized metals in the slag back into the bath. |
| **Ferrosilicon-Chrome** | Readily soluble material for making either furnace or ladle additions of chromium to steels. |
| **"SM" Ferrochrome** | Readily soluble material for making chromium additions to steel or cast iron in either the furnace or the ladle. |
| **Foundry Ferrochrome** | Especially for use in making ladle additions of chromium to cast iron. |
| **"CMSZ" Mix** | Combination hardening and graphitizing mixture for use as a ladle addition in making high-strength cast iron having good machinability. |
| **Chromium Metal** | For use in non-ferrous chromium-bearing alloys, such as electrical resistance alloys, high-temperature and corrosion-resistant alloys, metal-cutting tools, chromium bronzes, and certain high-strength aluminum alloys. |
| **Electrolytic Chromium Metal** | Contains a minimum of 99 per cent chromium. For use in the production of non-ferrous alloys, where even small amounts of impurities would be objectionable. |
| **"EM" Chromium Briquets** | For adding chromium to cast iron in the cupola. |

# Specializing

in the production of **CARBON AND ALLOY TOOL STEELS**

**SHEET AND PLATE MILL PRODUCTS** of all tool steel types

(All High Speed Steels are made at our Vanadium-Alloys Works, Latrobe, Pa.)



## COLONIAL STEEL DIVISION

Vanadium-Alloys Steel Company

**WIDELY-USED TOOL STEEL BRANDS PRODUCED BY COLONIAL STEEL DIVISION**

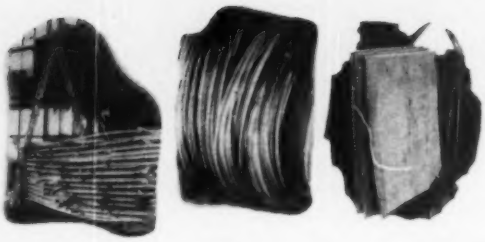
- Ohio Die
- Crocar
- Colonial No. 7
- Colonial No. 6
- Hotform
- Red Star
- Colonial No. 14
- Silmon
- Nikro M
- Air Hard
- Red Star Tungsten
- Speed-Cut

This fine plant—reconditioned since the war—is an important part of Vanadium-Alloys Steel Company's production facilities and an important source of supply for those who wish to use good tool steels. You are invited to inspect Colonial's up-to-the-minute equipment, including pyrometric control of melting, modern controlled atmosphere heating furnaces, supersonic testing apparatus and many other measures employed to insure FIRST QUALITY in all Colonial steels.

**Vanadium-Alloys**
**STEEL COMPANY**
LATROBE, PENNA.

Colonial Steel Division — Archer Brown Steel Co.

# To remove scale from bar, wire, sheet...

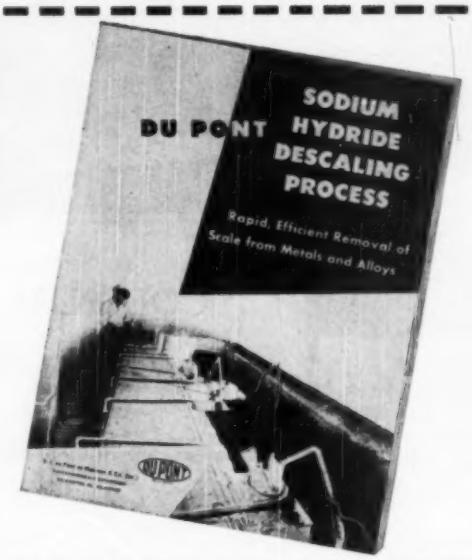


Stainless steels, tool steels, copper, nickel, in fact, any metal, alloy or bimetallic which does not react with molten caustic and whose physical characteristics are not adversely affected at 700°F., can be uniformly descaled, easily and quickly. Different grades can be treated simultaneously. Usual racking methods are sufficient.

# The efficient descaling method is this...

It's the Du Pont Sodium Hydride Descaling Process... that positively removes all scale quickly with no pitting, no pickling losses... that makes timing in the bath a simple matter... that can mean to you, in brief, important savings in time and money.

# This booklet tells the whole story...




It gives the many advantages of the process. Shows how they help *you*. Tells exactly what Sodium Hydride Descaling is, how it works and where it is used, along with interesting photographs, diagrams and technical information, designed to help you get the most out of your scale removal jobs. Send for it today! Clip the coupon and mail it to E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

**DU PONT**

**Sodium hydride process for nonelectrolytic descaling**

DU PONT

BETTER THINGS FOR BETTER LIVING... *THROUGH CHEMISTRY*

E. I. du Pont de Nemours & Co. (Inc.)
Electrochemicals Department
Wilmington 98, Delaware

Please send my copy of "Du Pont Sodium Hydride Descaling Process."

Name _____ Position _____

Firm _____

Address _____

# The Case of the Fabulous Family

When we at the McKay Company stop to think about it—our family of electrodes is indeed fabulous . . . for there are over sixty various types especially designed, developed and manufactured to meet almost every requirement for shielded-arc electrodes.

That's why—if you are weld-fabricating or weld-repairing any or all of the many mild-steels, the alloy-steels or the stainless-steels—you are sure to find a McKay Electrode of the type and size you need. Even if it's a special-purpose electrode for hard-surfacing or other unusual applications, you can be sure that there is a member of the McKay Electrode Family that can do the job and do it well!

* * * * * * * * * *

*If you are undecided as to the correct physical, chemical and metallurgical properties you require, why not contact a McKay Welding Engineer. He'll be happy to help you select the "one" electrode, from the McKay line that does your welding job more economically and better.*

**The properties of every McKay Electrode, accurately catalogued, are available on request. Our Technical Service Department welcomes your inquiry.**

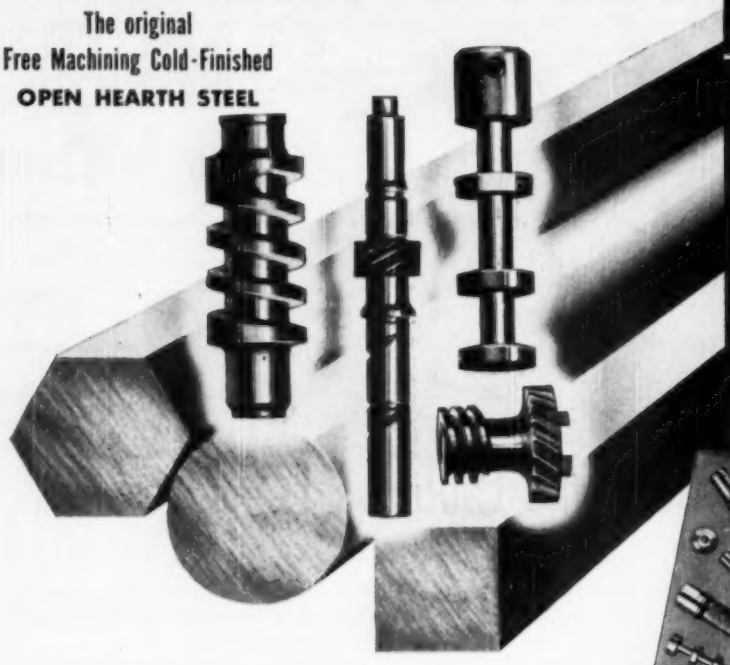
**McKAY STAINLESS STEEL • MILD STEEL • ALLOY STEEL • WELDING ELECTRODES**

**Researched, Developed and Manufactured to Fit Industry's Requirements for Dependable Electrodes**

# You can make them better with COLD-FINISHED

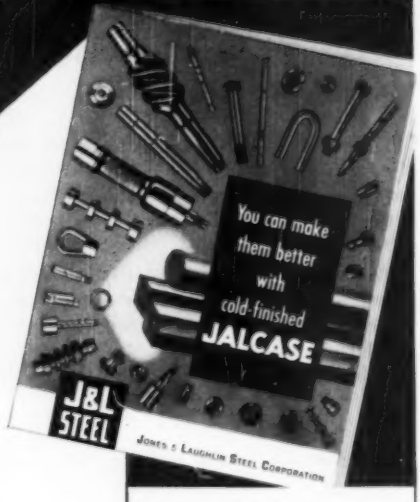
# J&L JALCASE

The original
Free Machining Cold-Finished
**OPEN HEARTH STEEL**



**J&L STEEL**

**IF YOU WANT GOOD**
. . . machinability
. . . heat treating properties
. . . high cold-drawn physical properties
**SAY J&L JALCASE**




★ **Available in a range of grades to suit a wide variety of applications.**

★ **Supplied as cold-drawn or cold-drawn-with-metallurgical-processing, which includes special tempering.**

Typical Jalcase analyses are found in the A.I.S.I. 1100 series. The usual manganese content is 1.00% to 1.65%. J&L, as the originator of these grades, can give you the benefit of years of know-how in the making of steel and the application of Jalcase to your particular requirements.

Some part you are now making can be made *better* from Jalcase with savings in money and time. Write us for a copy of "You Can Make Them Better With Cold-Finished Jalcase."

**JALCASE STEEL IS QUALITY CONTROLLED FROM OUR OWN MINES THROUGH THE FINISHED PRODUCT.**

## JONES & LAUGHLIN STEEL CORPORATION

*From its own raw materials, J&L manufactures a full line of carbon steel products, as well as certain products in* OTISCOLOY *and* JALLOY *(hi-tensile steels).*

**PRINCIPAL PRODUCTS:** HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURAL SHAPES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS

Jones & Laughlin Steel Corporation
405 Jones & Laughlin Building
Pittsburgh 30, Pennsylvania

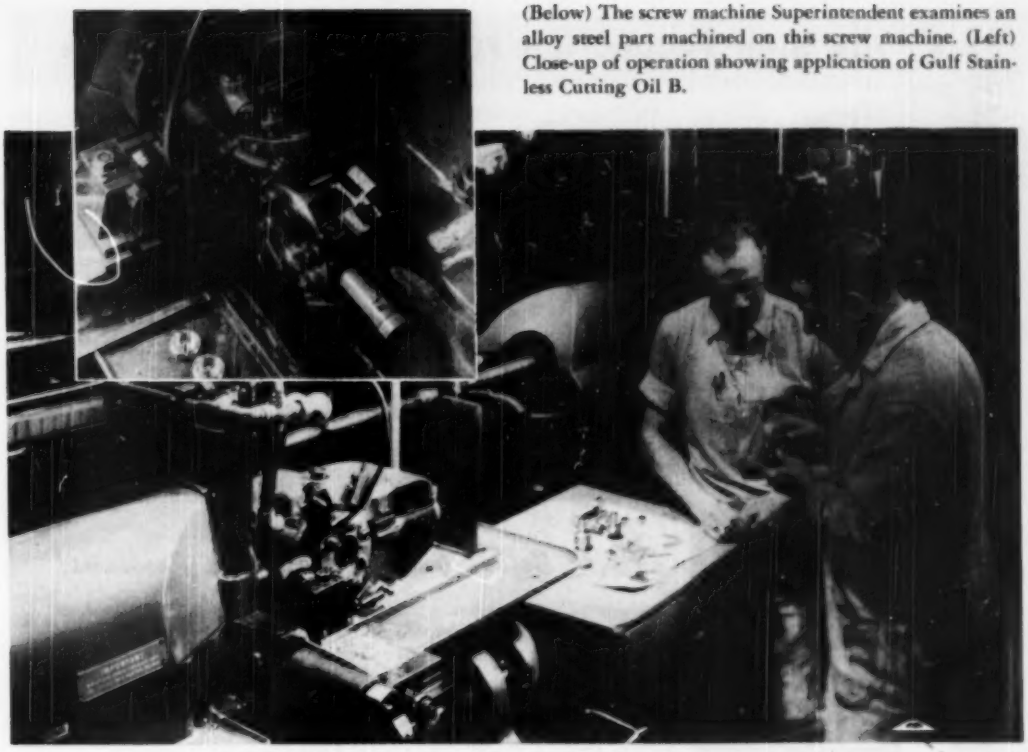
Please send me a copy of your booklet, "You Can Make Them Better With Cold-Finished Jalcase."

NAME_____

COMPANY_____

ADDRESS_____

(Below) The screw machine Superintendent examines an alloy steel part machined on this screw machine. (Left) Close-up of operation showing application of Gulf Stainless Cutting Oil B.



*"We get the extra fine finish we require with*

# Gulf Stainless Cutting Oil B"

*says this screw machine Superintendent*

"We have improved production on our screw machines since we switched to Gulf Stainless Cutting Oil B," says the screw machine Superintendent of this sewing machine manufacturing plant. "We get the extra fine finish we require and keep rejects to a minimum."

"We are working to a tolerance of .0005 inches on this alloy steel part, use 20 different gauges to check dimensional accuracy—and with Stainless Cutting Oil B we get this accuracy without a grinding operation."

A typical example of how the most suitable Gulf Cutting Oil improves machining practice! For practical assistance on your cutting oil problems, call in a Gulf Lubrication Engineer today. He will make specific recommendations which will help you get longer tool life, better finishes, and increased production.

GULF INDUSTRIAL LUBRICATION

**Gulf Oil Corporation · Gulf Refining Company** OFFICES IN PRINCIPLE CITIES IN 30 STATES

ROTARY AUTOMATICS • SEMI-AUTOMATICS • STRAIGHT LINE AUTOMATICS

• FOR HIGH PRODUCTION POLISHING AND BUFFING •

# ACME "Specials"

★ . . . Solve Unusual Finishing Problems!

In addition to Straightline, Rotary and Semi-Automatic Polishing and Buffing machines, *ACME* builds special machines to handle unusual or odd-shaped parts that cannot be effectively put on a production basis with other machines.

ACME "Specials" not only make it possible to finish parts that would be difficult, hazardous or impossible to handle manually, but also produce a uniform quality finish at low cost.

Among the unusual parts that are handled by ACME "Specials" are square, hexagonal, round and oval tubing; automotive reveal mouldings and mirror frames; plumbing goods, automotive and builders' hardware, electrical goods, gears and plastic items.

Grinding, polishing, buffing, burring, wire brushing, and abrasive belt finishing operations are handled at high production and low unit costs on ACME "Specials" . . . where parts are of a nature not suitable for handling on ACME Rotary, Straightline or Semi-Automatic machines.

★ *If a job can be done — an* ACME *will do it!*

SPECIAL MACHINERY AUTOMATIC BUFFING MACHINES

**ACME** *Manufacturing Co.*

1645 HOWARD ST. DETROIT 16, MICH.

*Builders* OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR OVER 30 YEARS

# These 2 TIMKEN® wear-resistant steels shipped in 24 hours!

**YOU CAN GET DELIVERY NOW FROM WAREHOUSE STOCK!**

TIMKEN* 52100 and Timken "Nickel-moly"—general purpose steels with good hardenability and wear resistance—will do 90% of your hollow parts jobs. And they're available in small quantities for immediate delivery within 24 hours of receipt of your order!

Timken 52100 is ideal for such machined parts as diesel injection pump parts, lathe centers, slitting knives and many other applications. It can be heat treated to file hardness and tempered back to any desired point. In moderate sections it is through-hardening. 52100 is available in 101 sizes, from 1" to 10½" O. D.

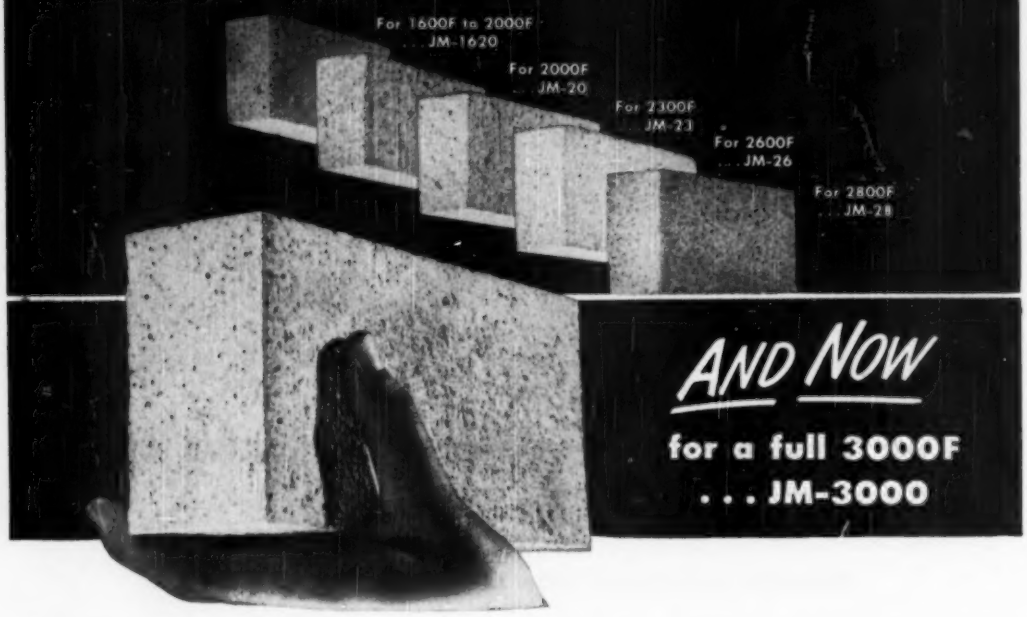
Timken "Nickel-moly" provides exceptional stamina and shock absorbent qualities. It is a low carbon, carburizing steel that develops high case hardness and tough inner core. 52 sizes range from 1.389" to 10.223" O. D.

You're assured of uniformity from tube to tube and shipment to shipment by careful quality control from melting through final tube inspection. For stock lists, write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

*Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing*

# *MEET* the family of Johns-Manville Insulating Fire Brick . .




## *AND NOW* for a full 3000F . . . JM-3000

HERE IS AN OUTSTANDING FAMILY of insulating fire brick for back-up or exposed use . . . the only family of its kind . . . that gives you a complete range . . . a *quick heating* insulating fire brick for every purpose.

By taking advantage of the quick heating characteristics of these insulating fire brick, you'll benefit through important savings in fuel because of the quicker rise to proper operating temperature in the furnace. This is a result of the low heat storage capacity and low thermal conductivity characteristics of the brick. These factors are especially important where furnaces are being intermittently operated.

The same materials can also be obtained in large size units as Johns-Manville Insulating Fireblok. This product has many advantages over the smaller size fire brick, from both a construction and stability standpoint. They can be quickly applied because they are easy to cut and fit. J-M Insulating Fireblok provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

Why not have a Johns-Manville insulation expert call to tell you more about ways in which you can save by using these insulations in your furnaces. Write Johns-Manville, Box 290, New York 16, N. Y. for further information.

| | JM-1620 | JM-20 | JM-23 | JM-26 | JM-28 | JM-3000 |
|---|---|---|---|---|---|---|
| Densities, lb per cu ft | 29 | 35 | 42 | 48 | 58 | 63-67 |
| Transverse Strengths, psi | 60 | 80 | 120 | 125 | 130 | 200 |
| Cold Crushing Strengths, psi | 70 | 115 | 170 | 190 | 150 | 400 |
| Linear Shrinkage,† percent | 0.0 at 2000 F | 0.0 at 2000 F | 0.3 at 2300 F | 1.0 at 2600 F | 4.0 at 2800 F | 0.8 at 3000 F |
| Reversible Thermal Expansion, percent | 0.5—0.6 at 2000 F | 0.5—0.6 at 2000 F | 0.5—0.6 at 2000 F | 0.5—0.6 at 2000 F | 0.5—0.6 at 2000 F | 0.5—0.6 at 2000 F |
| **Conductivity* at Mean Temperatures** | | | | | | |
| 500 F | 0.77 | 0.97 | 1.51 | 1.92 | 2.00 | 3.10 |
| 1000 F | 1.02 | 1.22 | 1.91 | 2.22 | 2.50 | 3.20 |
| 1500 F | 1.27 | 1.47 | 2.31 | 2.52 | 3.00 | 3.35 |
| 2000 F | — | 1.72 | 2.70 | 2.82 | 3.50 | 3.60 |
| **Recommended Service** | | | | | | |
| Back up | 2000 F | 2000 F | 2300 F | 2600 F | 2800 F | 3000 F |
| Exposed | 1600 F | 2000 F | 2300 F | 2600 F | 2800 F | 3000 F |

† *24-hr simulative service panel test for JM-3000, 24-hr soaking period for other brick.*

* *Conductivity is expressed in Btu in. per sq ft per F per hour at the designated mean temperatures.*

*Note: Above tests are in accordance with A.S.T.M. tentative standards.*

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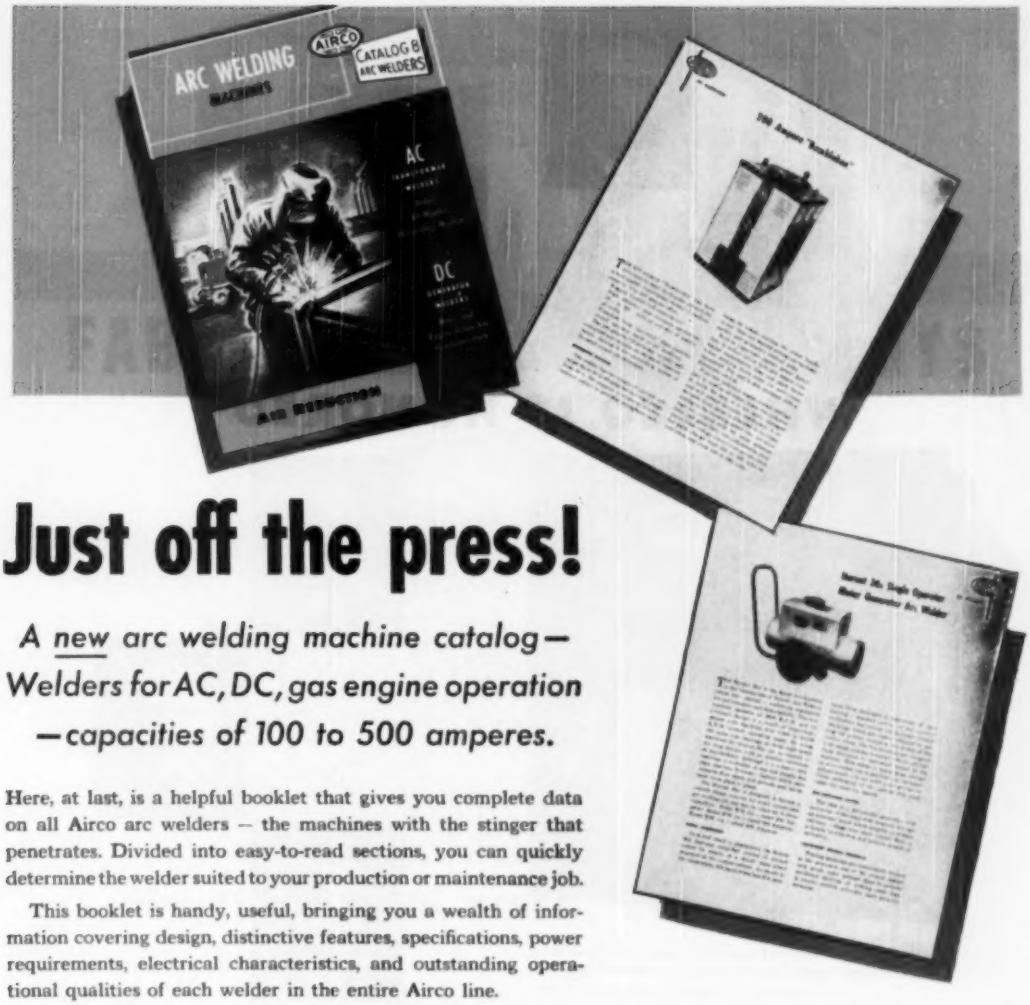


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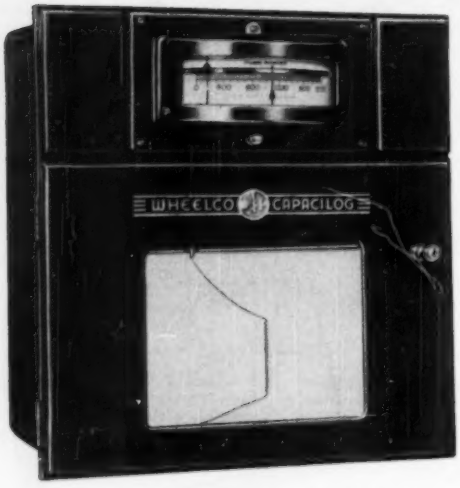

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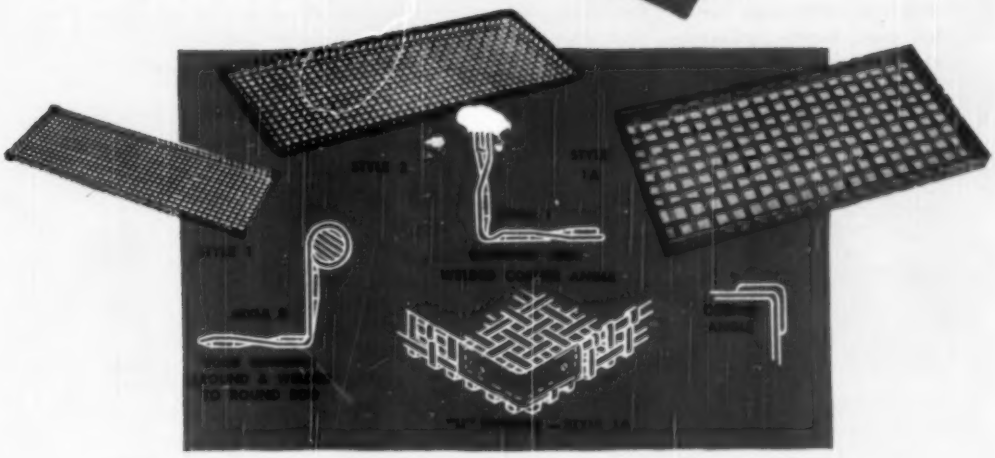

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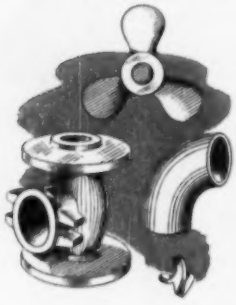

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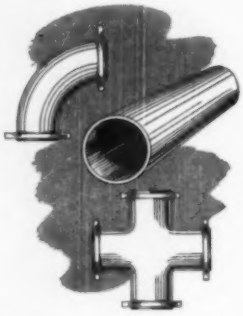

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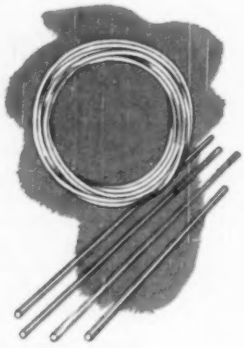

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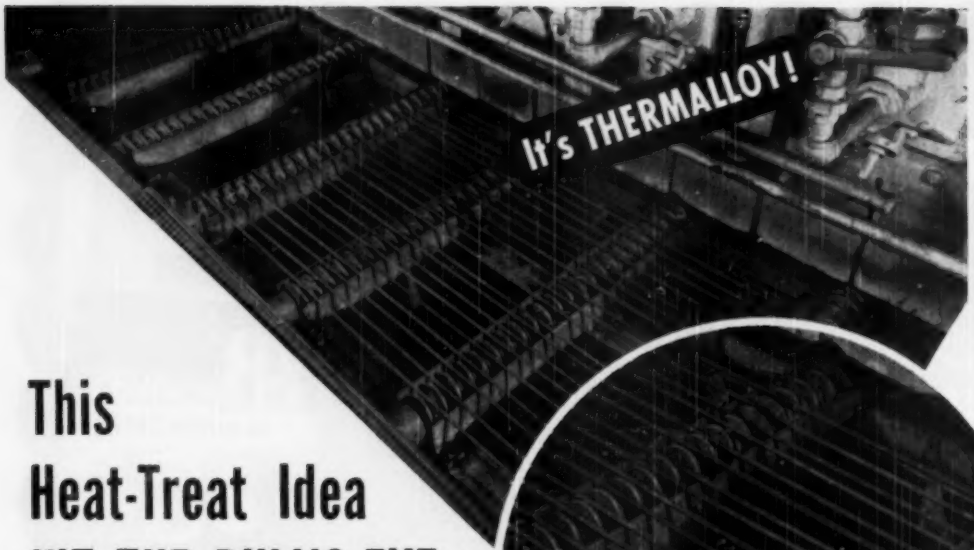


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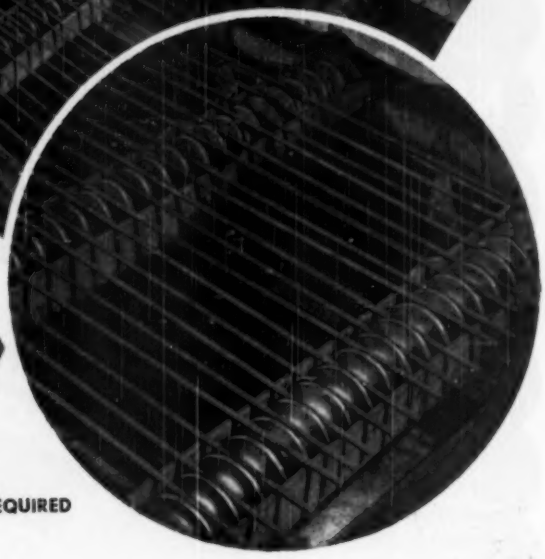

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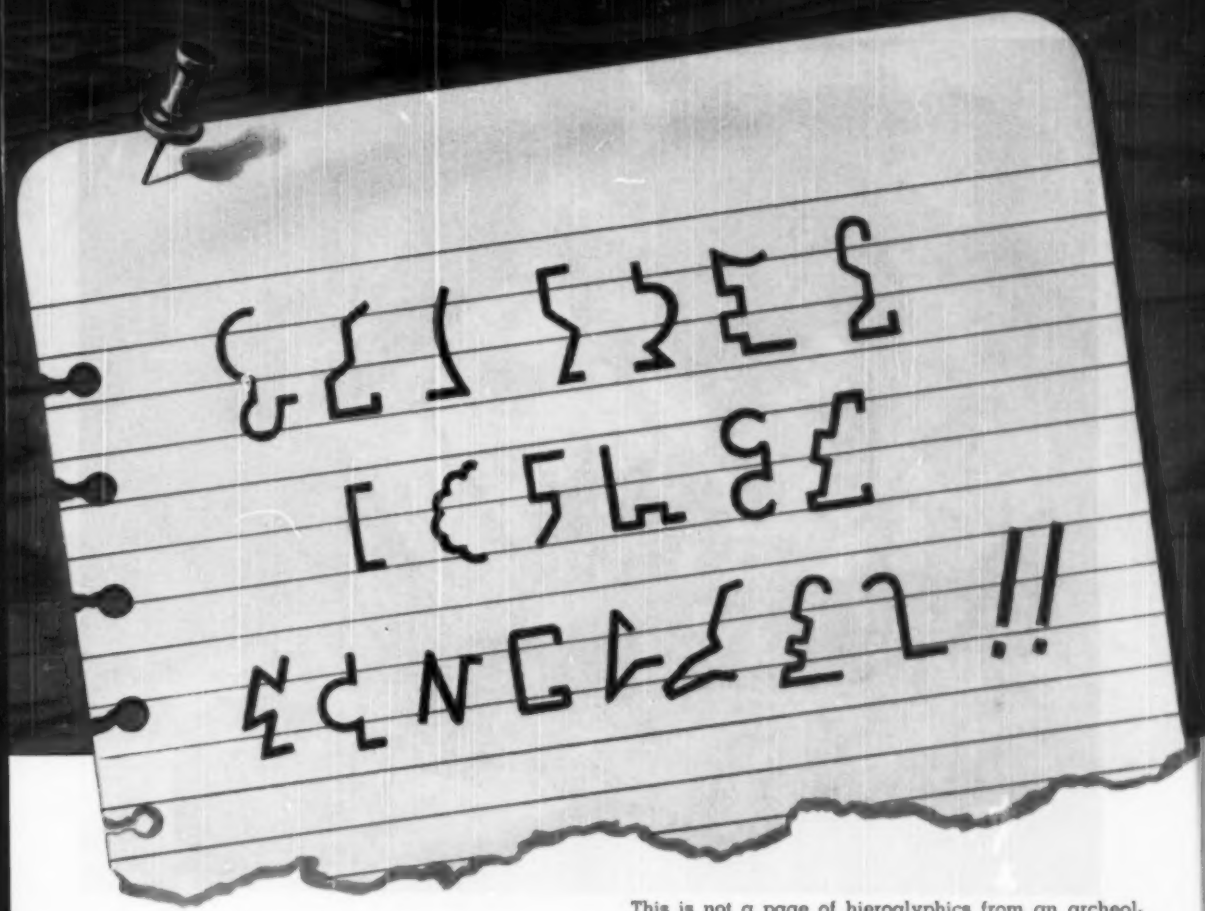

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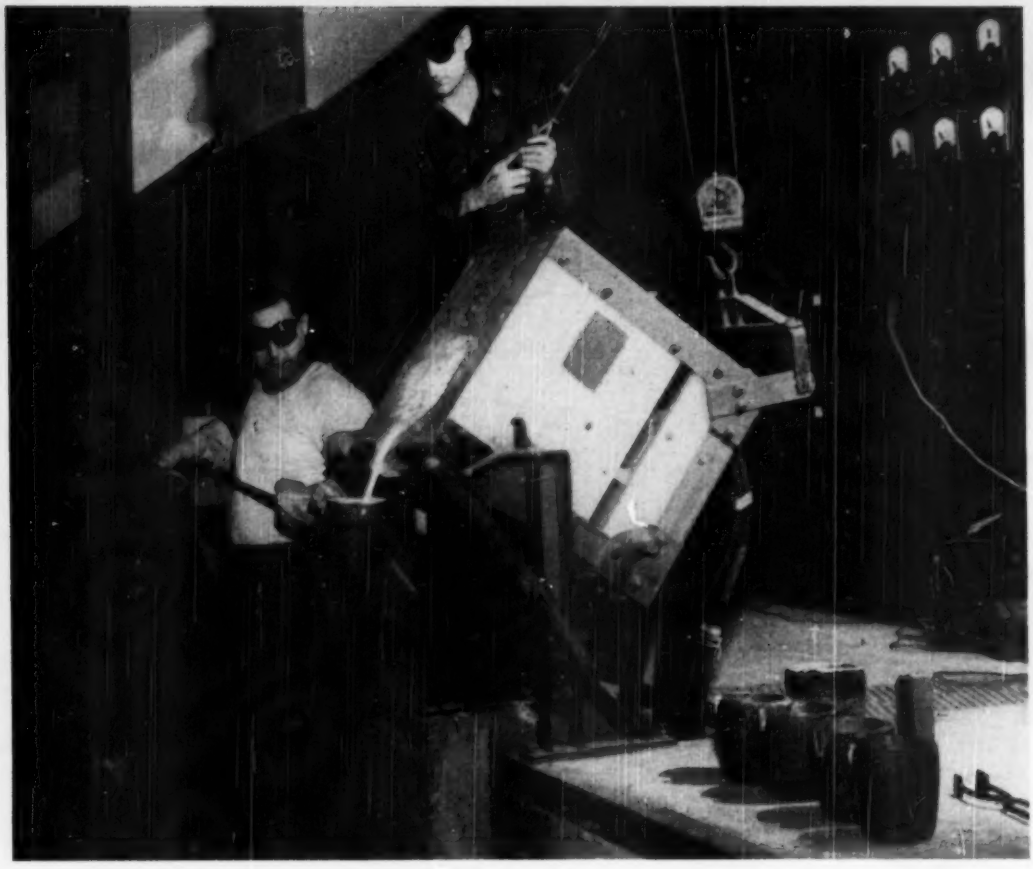

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# Metal Progress

**The Magazine for Metallurgical Engineers**

**January 1950**

**Vol. 57, No. 1**

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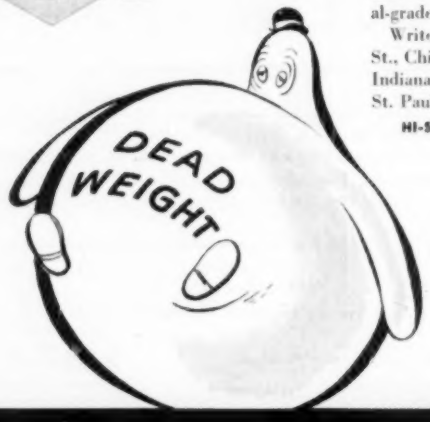


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# Continuous Casting of Brass Slabs

By Harold J. Roast
**Consulting Editor for Metal Progress**
Consulting Engineer
Montreal, P.Q., Canada

EARLY IN DECEMBER Scovill Mfg. Co. unveiled a new mill for the production of coiled brass strip in extra long lengths, a mill that is perhaps the most highly mechanized unit in the American brass industry. Furthermore, the method of casting the slabs in a continuous, practically automatic process is unique in the brass rolling industry. The new mill is a fitting capstone of 150 years of development.

Scovill is indeed a pioneering brass producing company in America. Standing by the main office building there is a flagstaff and at its base is an old grindstone. This serves as a reminder of the time in 1802 when the progenitors of the present Scovill Mfg. Co. converted the local flour and grist mill into the small beginning of a brass industry. Power was derived from the old waterwheel set up in the Mad River. Today the company derives its 15,000 kw. of electricity from high-pressure steam boilers, and its water for cooling purposes in the mill and for general use comes from seven lakes used as reservoirs and owned by the Scovill company.

The variety of products has grown to over 300,000 items (including many parts made in steel, aluminum, and other alloys as well as brass). Furthermore, the venture has been profitable; Scovill has paid dividends uninterruptedly for the last 100 years!

As one enters the new mill he could not but be impressed by the quiet that prevails and the few men visible in the huge building. Good housekeeping is evidenced to the last degree, and unostentatious efficiency becomes more and more evident during the tour. All that can be done within the limits of such an article as this is to summarize briefly in logical sequence the various stages of manufacture from the sorting, iron removal, and weighing of the metal charges, to the melting and casting. Rolling, slitting, heat treating and finishing of the final coils, ready for shipment, must be reserved for later consideration.

## The Melting Department

The charge, having been passed over magnetic devices to remove every trace of free iron, is weighed into containers and carried by crane to the Ajax-Scomet furnaces, of which there are at present two in operation with a third to follow shortly. These furnaces were built by the Ajax Engineering Corp. of Trenton, N. J. The name indicates the association of three companies—Ajax, Scovill Mfg. Co., and American Metal Co. of N. Y., the latter two having been long interested in large furnaces for manufacturing oxygen-free, high-conductivity copper. Each of the Scovill furnaces, shown in cross-sectional drawings Fig. 1A and 1B, will melt 10,000 lb. of metal charge per hr., so that at the time of the visit 20,000 lb. of brass was being supplied to the system every hour, day and night.

To facilitate charging, the metal is delivered to a vibrating scoop that shoots it into the open top of the furnace. As the latter is never more than half empty, very little disturbance is produced thereby. To a veteran foundryman it is particularly interesting to note how little zinc fume escapes, notwithstanding the fact that much of the charge is of light gage brass sheet scrap. The fact that the total zinc loss is well under 2% is further proof of the efficiency of melting. These furnaces are unique and the largest brass furnaces yet made, and consequently merit full description.

The furnace consists of a hexagonal steel drum between circular ends. The lining is made of refractory shapes and standard bricks. Three detachable inductor units, each rated 333 kw., are fastened to the lower part of the drum; in them the heat is generated within channels, exactly as in the pioneering Ajax-Wyatt low-frequency fur-

nace introduced in brass mills a little over 30 years ago. In each of the triple units the melting channels form two secondary loops, interlaced with two primary coils, and this circuit must be considered as the secondary winding of a short-circuited transformer in which a current of many thousand amperes flows. The heat is dissipated to the cold metal charged into the drum by the well-known movement caused by electromagnetic forces in low-frequency induction furnaces. In each of these triple units two primary windings surround a closed transformer core. Power supplied is at 575 volts, 60 cycles, three phase, with all phases balanced.

As stated above, the inductor units can be detached and replaced without interrupting the operation of the furnace by turning the drum so as to bring the inductor which has to be changed above the molten metal line, thus draining the channels while keeping the metal hot with the two remaining inductors. The damaged inductor can then be replaced with a new one. Each inductor unit has two blowers for cooling the transformer core and the primary windings.

For rotating the drum a motor-driven speed reducer and two chains are used. On both ends of the hexagonal furnace binding, two tires (noted on the drawings as "rotating drums") are provided, which ride on trunnions as shown. It is thus possible to turn the furnace completely over, so that any of the three inductors, including the lower one, can be emptied for the purpose of replacing them. The rotating device is also used to discharge metal from the drum through the tap hole or pouring spout. The capacity of these furnaces (maximum of 22,000 lb.) has been reduced as much as possible to facilitate rapid change of alloys, which is a requirement of no little importance in a brass mill. Temperature control is by permanently inserted thermocouple, and automatic power changing devices.

Many advantages are claimed and hoped-for by the metallurgists who designed and installed these units. In connection with the continuous casting process yet to be described, they provide highly uniform composition in slab ingots. Charging is easy; the charging machine dumps large amounts of metals containing virgin metal and

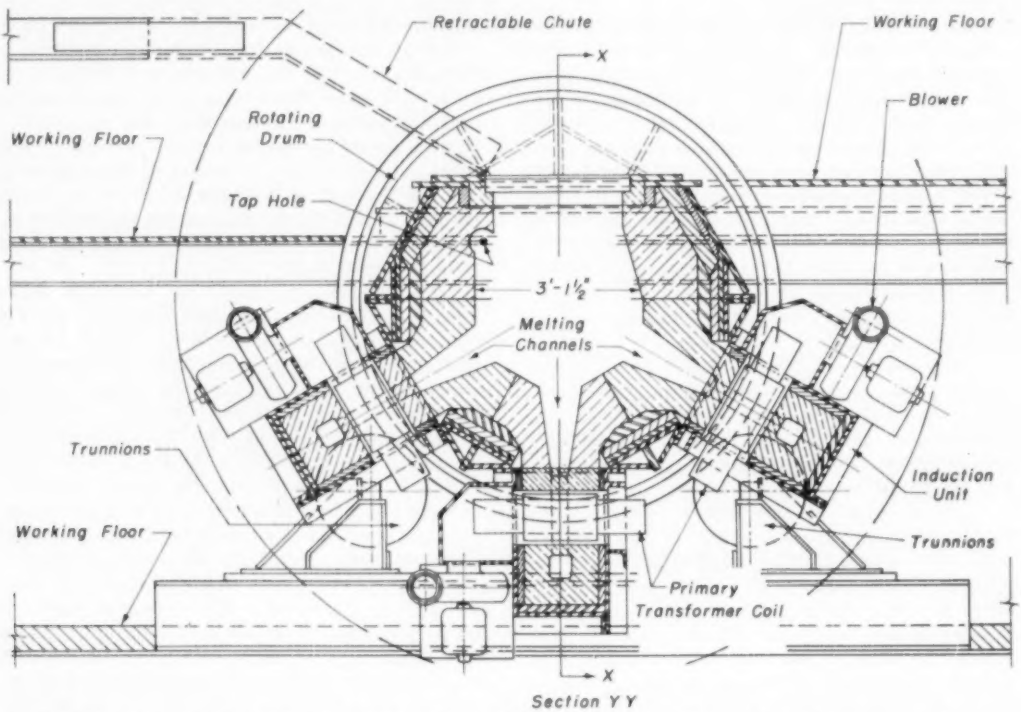



*Fig. 1A — Cross-Sectional Elevation of Ajax-Scomet 1000-Kw. Induction Furnace for Melting Copper Alloys*

scrap of all kinds into the wide-open furnace top. Two furnaces are operated with two men. The large amount of metal retained in the drum facilitates fast melting of cold metal. Because the melting channels are straight, they can be cleaned from time to time to prevent clogging or obstruction of the melting circuit. Change of alloys is not difficult because the furnace can be completely emptied.

## Continuous Casting

F. M. Barry, director of metals research department, was kind enough to outline briefly the development of the continuous casting process in Waterbury. Officials from Scovill went to Germany in 1936 and inspected a Junghans continuous casting machine there in operation; the company later purchased rights, erected a machine, and by 1938 was in production of round billets of copper-base alloys.*

*Editor's Note — Other data indicate that 6-in. rounds of cupronickel were cast continuously by Scovill by the so-called Eldred process earlier — in 1934.

The results were not too satisfactory, and much study and not a few changes were made in the equipment. Later the Rossi company made a new machine, and the present flat-slab installation consolidates experience gained from these sources.

This observer would believe that the holding furnace and attached pouring devices are the heart of Scovill's continuous casting operation, since the transfer of molten metal from a holding furnace into a water-cooled mold at the precise rate the metal solidifies has long been practiced by the aluminum industry for the casting of alloy ingots or slabs. (This statement is made without the least intent to minimize the achievements of the brass industry.) The casting of aluminum ingot is discontinuous to the extent that, at the very beginning, the mold's bottom is closed by a plate or platform supported from below by a hydraulic piston. As the metal solidifies, this base plate is withdrawn slowly downward at a rate exactly balanced to solidification, so the liquid level remains constant in the fairly shallow mold. When the slab has reached correct length the flow

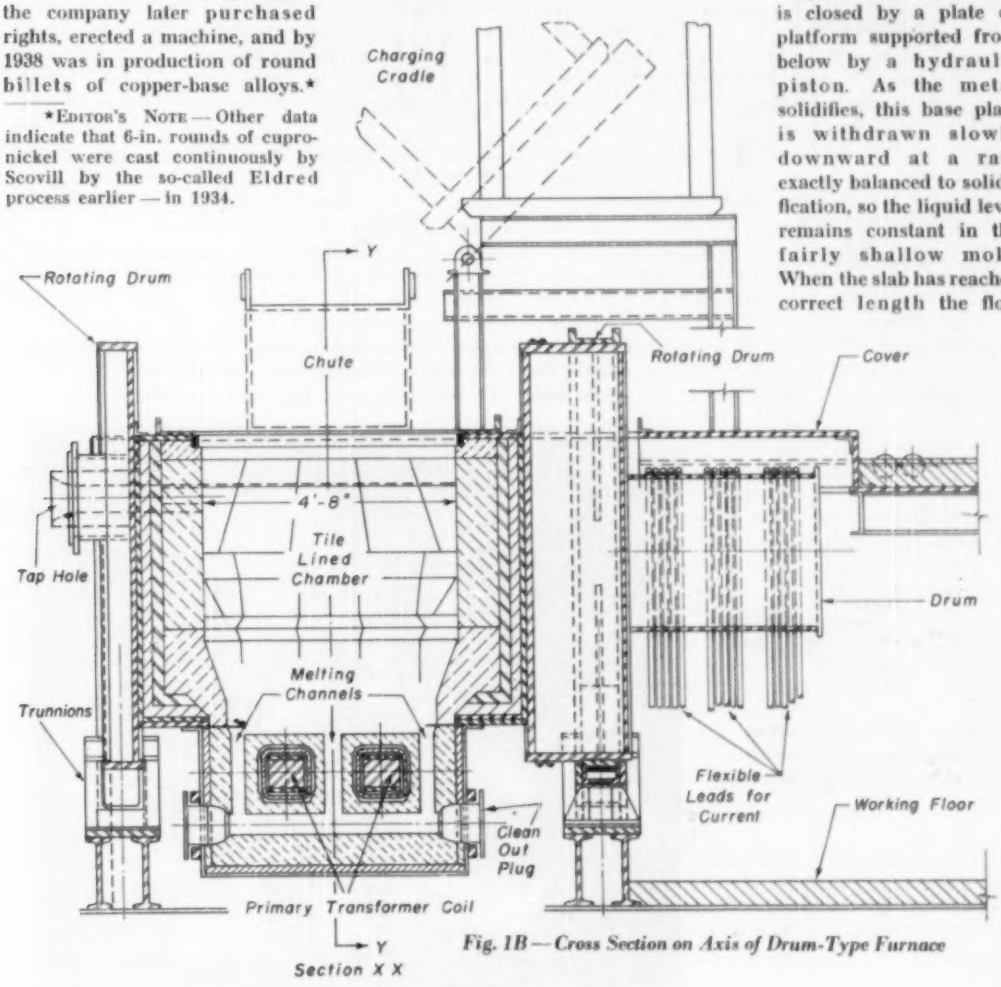



*Fig. 1B — Cross Section on Axis of Drum-Type Furnace*

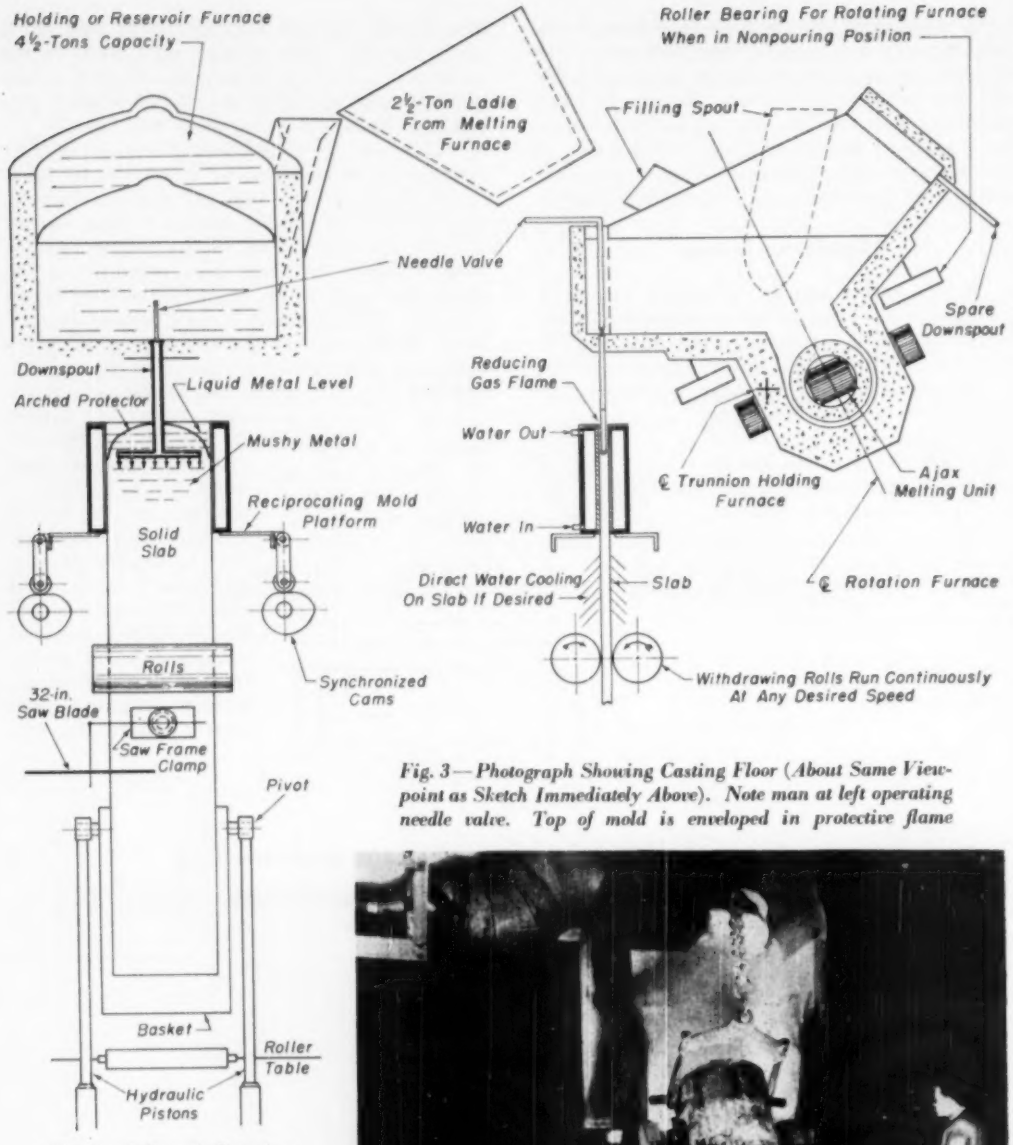
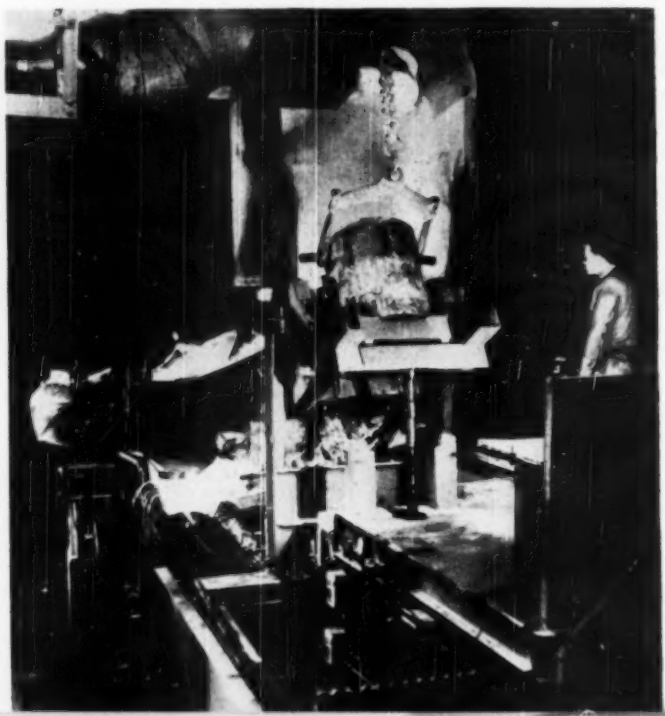



*Fig. 2 — Schematic Drawing of Continuous Slab Casting Machine (Junghans-Rossi)*

*Fig. 3 — Photograph Showing Casting Floor (About Same Viewpoint as Sketch Immediately Above). Note man at left operating needle valve. Top of mold is enveloped in protective flame*



of molten metal is stopped, the residual metal in the mold sofidifies, the slab ingot is removed, the hydraulic platform is raised to close the underside of the mold, and the process starts all over again.

Reference to the drawings in Fig. 2 will show that (once the copper casting has been started, by means analogous to the above) the slab is continuously cast, being drawn downward at the correct rate by pinch rolls, and cut to desired lengths by a flying saw. Details of this operation will be given after the holding furnace and pouring devices are described.

Molten metal from the Ajax-Scomet furnaces is tilted into a suitable ladle which holds some 6000 lb. This is then transferred by crane to the holding furnace, which also is never allowed to empty beyond the capacity of the next ladle of metal to fill it — except when it is desired to change the analysis being cast. This holding furnace has a capacity of 9000 lb. and has a 120-kw. Ajax low-frequency induction unit in its bottom to maintain the desired temperature in the molten metal.

As shown in Fig. 2 and 3, the furnace has two diametrically opposite sets of spouts, each set consisting of a pouring downspout, a receiving funnel, and an emergency dump spout. When metal is being cast, the furnace is tipped 25° and the bottom end of the front downspout is submerged in liquid metal in the water-cooled mold below. When not running, both downspouts are sticking out of the horizontal furnace at 25° from vertical, with upper ends above the liquid metal line in the furnace. If minor trouble is encountered at pouring, the machine is tipped back to horizontal (stopping casting), revolved 180° to use the reserve downspout, the furnace is tipped, and the machine starts casting again.

## Downspout for Molten Metal

We now come to the very heart of the whole process, namely, the tube through which the molten brass continuously runs from the bottom of the holding furnace into the water-cooled mold that receives fluid metal at its entrance and delivers solid metal at its exit. The process is continuous; the slabs, 24 in. wide and weighing some 2000 lb. each, are derived by the simple process of cutting off equal lengths as the red-hot metal, in a plate 2½ in. thick, keeps steadily appearing.

The downspout appears to the observer as a red-hot tube reaching between the bottom of a tub-like container and the semiclosed mold top. (These parts, submerged in liquid brass or carrying the metal, are made of 25% chromium-iron alloy.) To watch this red-hot tube, which is the only source of supply for the metal of the whole of the huge mill, is to be fascinated by the ingenuity that has culminated in this concentrated, steady flow of high-purity brass, free from gas, oxides and other impurities. It is hard to credit that through a ½-in. tube is passing 20,000 lb. of metal every hour!

As shown in Fig. 2, the downspout ends in a horizontal crosspiece, thus taking the form of an inverted T. Molten metal is distributed from this horizontal into the mold beneath through a series of suitable holes. The volume of flow can be controlled by a needle valve at the upper end, and the whole of the operation of pouring the metal into the mold, its progress through the mold, and the sawing off of the slabs from the emerging "ribbon", are all under practically perfect automatic control — including speed and temperature. Molten metal at the top of the solidifying portion in the mold is protected from oxidation by spraying it with sperm oil. An arched protector, easily sliding in the mold, keeps most of the air out and the vaporized sperm oil in; further protection at the mold's mouth is given by a mantle of gas flames.

Examination of the drawing (Fig. 2) indicates that the water-cooled copper mold reciprocates slowly up and down — the downstroke being synchronized with the discharge rate of the bar; the upward stroke returns at three times that rate. In the position indicated in the drawing the mold is at the bottom of its travel and contains enough solidified, strong metal in its lower portion so the mold can be brought up, sliding along the hot slab, to where the level of molten metal is about the center of the mold. The Tee crossbar of the downspout, of course, is also stationary and remains always submerged in the upper layer of molten metal in the mold. Meanwhile, and at all times, the bar or slab is brought downward at a constant speed by a set of withdrawing rolls.

## Slabs Cut to Length

The saw which cuts the slabs to desired length is hydraulically clamped to the slab during cutting, thus allowing the whole saw assembly to move down at slab speed. The cut-off portion is caught in a basket, tilted to horizontal, and carried away on roller tables to an inspection station. Soon it will be on its way to the first stand of the new rolling mill.

This rolling mill is of such importance that a separate article will be presented on the mechanical devices, as well as a third on the furnaces for process and finish annealing, and the continuous pickling and cleaning units.

# Where Will We Get Our Future Metals?

**By John D. Morgan, Jr.***
National Security Resources Board
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*The U.S. mining industry does not supply many necessary metals. For example, in recent years we have been dependent on foreign sources for more than 90% of our beryllium, chromium, cobalt, columbium, nickel and tantalum. Numerous problems of the domestic mining industry were not solved satisfactorily in World War II. These problems may be even more important in a future emergency.*

JUST BEFORE the second World War, 14 materials were listed as "strategic" and 15 were listed as "critical" by the Army-Navy Munitions Board. Seven strategic and three critical materials were metals. Today the Munitions Board lists nearly 70 strategic and critical materials that are being stockpiled, and many other essential materials that would offer supply problems in an emergency. The most recent compilation of the strategic and critical materials being stockpiled includes the following metals and ores: aluminum, antimony, bauxite, beryl, bismuth, cadmium, chromite, cobalt, columbite, copper, iridium, lead, magnesium, manganese ore, mercury, molybdenum, nickel, platinum and the other platinum metals, rutile, selenium, tantalite, tin, tungsten, vanadium, zinc, and zirconium ores.

In an emergency, domestic mine production, secondary recovery and stockpiles are the most certain sources because they involve no production problems in distant lands and no external transportation. Imports of metals and pure minerals are more desirable than imports of ores and concentrates because the latter will require additional shipping space and further processing in the United States. Stockpiling is intended to cover estimated deficiencies in an emergency when probable requirements are compared with probable supplies available from protected sources. If the materials stockpiled are in the most advanced state possible (that is, metal bars instead of piles of ore) they become of greatly increased value in an emergency, for they then represent additional stockpiled transportation, power, labor and time.

From the yearly volumes of the Bureau of Mines "Minerals Yearbook", the author has prepared a series of charts covering representative major metals and minerals, all of which are highly essential in modern war. These charts, shown on the facing page, compare the amounts of material obtained from all sources except stockpiles. Prewar stockpiles are not included on these charts because most of the stockpile goals were much too modest in the light of later requirements, and little material was actually on hand in the government stockpiles at the start of the war. Table I compares the prewar stockpile goals and shows the stockpile status of the representative materials charted.

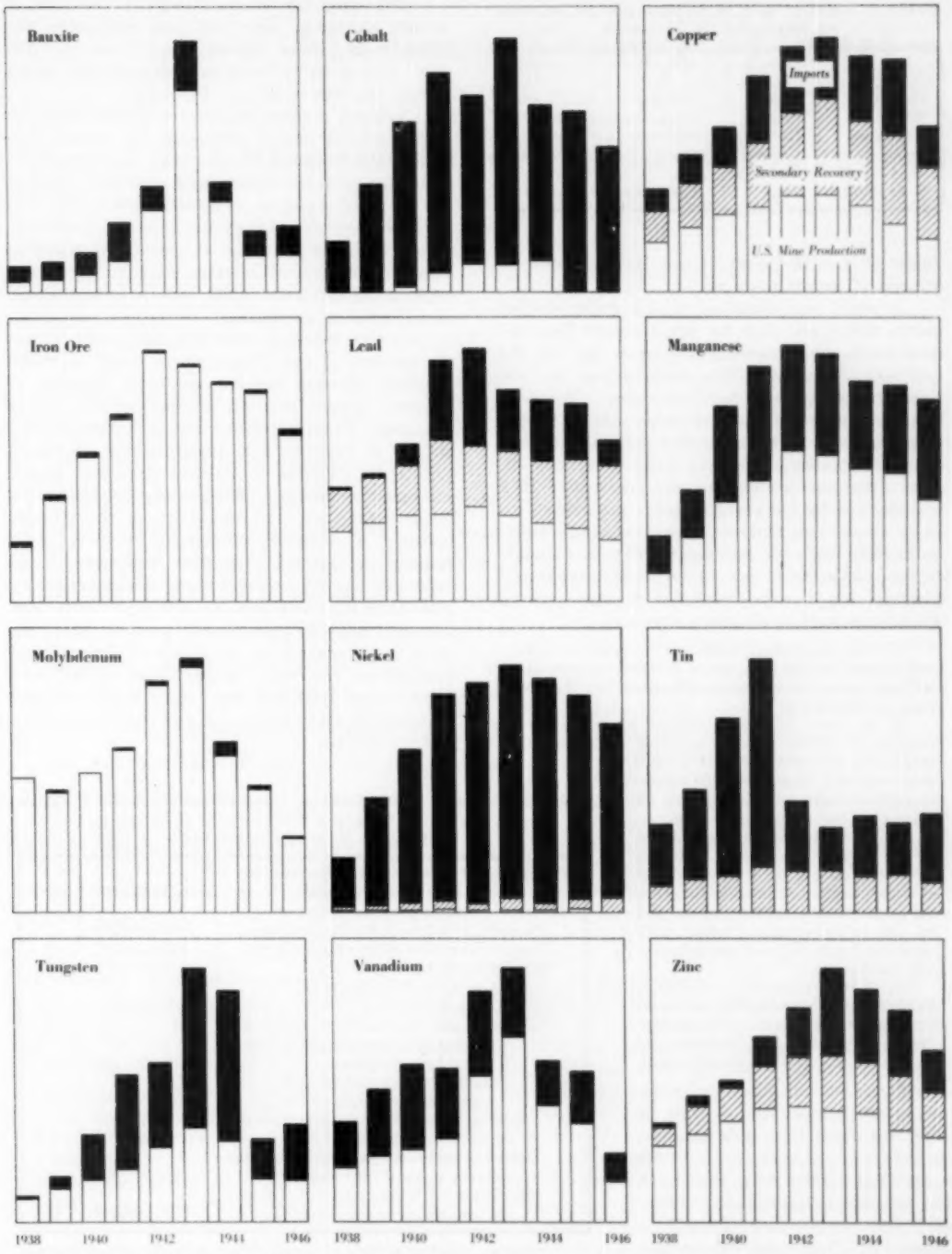
**Table I — Prewar Status of Selected Major Metals and Minerals in the Government Stockpile Program**

| Material | Stockpile Goals as of June 1941 | On Hand in Stockpile as of Jan. 1, 1942 |
|---|---|---|
| Chromite | 1,950,000 tons | 320,000 tons |
| Copper | 500,000 | 69,187 |
| Lead | 100,000 | 17,934 |
| Manganese Ore | 3,696,000 | 572,000 |
| Tin | 242,000 | 50,039 |
| Tungsten Ore | 28,560 | 7,246 |
| Zinc Concentrates | 150,000 | 88,697 |

There was authority to purchase nickel in Brazil.

Source: "Special Study No. 30 — Import Policies and Programs of the War Production Board and Predecessor Agencies, May 1940 to November 1945", by David Horton. Washington, Civilian Production Administration, May 1, 1947.

*The opinions expressed are those of the author and do not necessarily reflect official views. This article is based on Dr. Morgan's recent book "The Domestic Mining Industry of the United States in World War II — A Critical Study of the Economic Mobilization of the Mineral Base of National Power", printed by National Security Resources Board, 1949.




*U.S. Imports (black), Secondary Recovery (crosshatched) and Mine Production (white) of 12 Important Metals and Ores*

**Table II — Extent of U. S. Dependence on Imports of Major Metals, 1942-1944**

| 0 TO 25% | 25 TO 50% | 50 TO 75% | 75 TO 100% |
|---|---|---|---|
| Bauxite | Copper | Antimony | Beryllium |
| Boron | Lead | Manganese | Chromite |
| Cadmium | Mercury | Platinum | Cobalt |
| Iron Ore | Iridium | Silver | Columbium |
| Magnesium | Vanadium | Tin | Nickel |
| Molybdenum | Zinc | Tungsten | Tantalum |

Table II is a summary of our dependence on imports of metals and ores.

A rapid consideration of the accompanying charts will reveal that for many metals domestic mine production reached a maximum in 1942, the first year of the war. This situation was true for iron ore, manganese, lead and zinc. Domestic mine production of bauxite, copper, molybdenum, tungsten and chromite reached maxima in 1943. Domestic mining of tin and nickel was insignificant. For most metals the war years after 1942 brought greatly increased reliance on imports to make up our deficiencies of major strategic materials. The domestic mining industry was unable to keep pace with the increased emergency demands for several significant reasons, among the most important of which were:

1. The increasing depletion of reserves without corresponding discoveries of new deposits and without sufficient development to maintain the 1942 rates of extraction.
2. A labor shortage caused by the prewar exodus of skilled men to airplane factories and shipyards, by the drafting of 126,000 miners from a total of 606,000 miner-registrants, and by the drifting of miners to low-productivity mines.
3. An equipment shortage caused by the general shortage of materials and components, by the conversion of many machinery manufacturers to the production of military items, and by our supplying our allies with significant quantities of needed mining machinery.
4. Administrative confusion incident to the pyramiding and overlapping of emergency mobilization agencies and existing Federal and State agencies in the minerals field.

Today our situation is in many ways still comparable to that in 1941 (see Table III). For example, imports of manganese ore in 1948 came from the following sources in the proportions indicated: U.S.S.R. 36%, India 19%, South Africa 18%, Brazil 11%, Gold Coast 6%, Mexico 5%, Cuba 3%, Others 2%.

The situation in metallurgical chromite is equally alarming: Our 1948 mine production was insignificant, while imports came from: U.S.S.R. 43%, Turkey 25%, Southern Rhodesia 12%, South Africa 7%, New Caledonia 6%, Others 7%.

National security requires intensive attention to the mineral supply problems that would exist in a future emergency. Logical and integrated estimates of requirements and available supplies are the first requisite. Potential deficiencies can then be detected and remedial measures indicated. In special cases assistance to permit the exploitation of submarginal reserves may be necessary, while some materials might require greatly accelerated rates of stockpiling.

Certain minerals that are not found within the borders of the United States must be made available through assured access to deposits in friendly nations that are located on protectable sea-lanes. Prompt development of acceptable substitutes is required for materials that obviously cannot be supplied in desired quantities under emergency conditions. Mobilization planning must involve complete consideration of the mineral industry if a future emergency is to be met. Indeed, our present industrial civilization is so dependent on the products of the mineral industry that economic planning of any type must give adequate consideration to the peculiar problems of mineral economics. In a world where strong civilizations are built largely upon metals and minerals we must give due regard to the mineral foundations upon which rest our continued safety and prosperity.

**Table III — Status of the Postwar Government Stockpile Program**
(As of June 30, 1949, and Reflecting the Congressional Reduction Made in October 1949)

| | | |
|---|---|---|
| Total estimated five-year-war requirements of those materials being stockpiled | $10,736,000,000 | 100% |
| Which are assumed to come from: | | |
| Domestic production during the war | 3,563,000,000 | 33 |
| Imports from accessible sources in war | 3,956,000,000 | 37 |
| Stockpile (when complete) | 3,217,000,000 | 30 |
| Total on hand in stockpile as of June 30, 1949 | 914,000,000 | 9 |
| composed of: | | |
| Material from prewar stockpiles and from surpluses | (524,000,000) | (5) |
| Material purchased through postwar programs and E.C.A. | (390,000,000) | (4) |
| Material financed and programmed for delivery in fiscal 1950 | 627,000,000 | 6 |
| Material financed and programmed for delivery in fiscal 1951 and later | 473,000,000 | 4 |
| Stockpile still unfinanced and requiring congressional appropriations | 1,203,000,000 | 11 |

SOURCE: "Stockpile Report to the Congress", Munitions Board, July 23, 1949, and Munitions Board Staff.

# Aluminum Coating of Steel—

# A Comparison of Various Processes

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Aluminum Co. of America
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*Steel can be coated with aluminum by hot dipping, cladding, electroplating, spraying, chemical reaction and calorizing. In this article the authors discuss the coatings produced by each of these methods. Particular emphasis is given to the importance of controlling the thickness of iron-aluminum compound that forms between pure aluminum surface layer and steel base. In the table at the end of the article, the six methods of coating are compared on the basis of structure and cost.*

THE APPLICATION of an aluminum coating to steel has long been desired, and numerous efforts have been made to develop a successful process. The search for a commercial process has been hastened by the need for conserving many of the metals that are now being used for alloying and coating steel products. In some applications, aluminum coated steels might replace the highly alloyed corrosion resistant and heat resistant steels; this would permit the use of low-alloy steel with a carbon content sufficient to meet the strength requirements, while the aluminum coating would provide the necessary protection against corrosion and scaling and thus conserve alloying metals.

Aluminum coated steel has shown a high resistance to rusting in industrial and seacoast exposures, and has been found superior to steel with galvanized coatings of similar thickness in industrial and humid atmospheres. The presence of several per cent of aluminum in the surface of iron or steel products markedly decreases the scaling caused by oxidation. The maximum effect is obtained at about 10% aluminum, with no greater resistance to oxidation as the aluminum content is increased above 10%.[1, 2, 3] [References start on p. 63.] Higher aluminum contents are harmful in causing embrittlement.

The applications for aluminum coated products may be divided into two groups: One requires a surface layer of iron-aluminum alloy to resist scaling; the other depends on an aluminum coating for protection against corrosion.

**Iron-Aluminum Compound** — The one problem common to all processes for coating with aluminum is control of the formation of iron-aluminum compound, which consists of several of the intermediate phases in the iron-aluminum system. The importance of controlling the formation of this compound is not sufficiently emphasized in previous reviews.[4, 5, 6] For resistance to oxidation and scaling, the compound should not form to such an extent that the surface becomes brittle and spalls. When the aluminum content of the surface zone approaches 50% a brittle condition exists. The real protection is probably afforded by a layer of aluminum oxide on the surface of the iron-aluminum alloy.

The iron-aluminum compound is not desired as the surface layer when protection against corrosion is the object of the coating. When present as an interfacial layer the compound interferes with bending and forming operations. Iron-aluminum compound originates whenever steel is heated in contact with aluminum at a temperature above about 1100° F. and increases as the time is increased. The formation of an interfacial brittle zone of this material occurs during the annealing of aluminum coated steel products. Figure 1 shows

a typical example of the coating produced by hot dipping mild steel sheet in pure aluminum; the interfacial compound layer is about the same thickness as the surface layer of aluminum — a very undesirable condition. Figure 2 shows a hot dipped coating after heat treatment for 15 min. at 1400° F.

A few alloying additions hinder formation of iron-aluminum compound. Some benefit is obtained from addition of silicon[7] to the aluminum, and the presence of silicon[6] or chromium[8] in the steel.

## Coating Processes

Processes proposed for impregnating or coating ferrous metal products with aluminum are: *(a)* packing in aluminum powder, *(b)* reacting aluminum chloride with iron, *(c)* spraying, *(d)* electroplating, *(e)* cladding, *(f)* casting aluminum around steel, *(g)* casting steel around aluminum, and *(h)* hot dipping.

**Packing in Aluminum Powder** — One of the early processes was the now widely known calorizing method, which consisted of packing the iron products in a powder containing aluminum and ammonium chloride and then heating to cause coating and impregnation to occur.[9, 10, 11, 16] The charge was heated for several hours in a neutral atmosphere, in tightly sealed stationary boxes or rotating drums, at temperatures between 1500 and 1800° F. This provided a layer many mils thick, but of such a high aluminum content that it was brittle. Brittleness was overcome by a subsequent heat treatment in the absence of aluminum, permitting further diffusion and reducing the aluminum content of the surface zone to give a microstructure similar to Fig. 2.

Krupp used a modified calorizing process known as "alitizing" in which a 50% iron-aluminum alloy was substituted for aluminum powder, and no special atmosphere was required.[5] The impregnated zone contained only 10 to 15% aluminum, which possesses as good resistance to scaling as higher aluminum contents and has improved ductility and adhesion.

**Reacting Aluminum Chloride With Iron** — A chemical reaction between aluminum chloride and iron at 1700° F. to produce an aluminum coating is the basis of the Martin process.[12] Laboratory tests have shown that this reaction forms a layer of iron-aluminum alloy so thin that little or no protection is provided.

**Spraying** — Steel can be sprayed with aluminum by either the wire or powder method.[4, 13] The sprayed coatings contain oxide films and pores; there is no interfacial iron-aluminum layer (Fig. 3). Despite the pores, sprayed aluminum coatings protect the steel base electrochemically against corrosion. Thickness varies from 2 to 20 mils; coatings thicker than 10 mils are likely to peel and flake during heating and cooling.

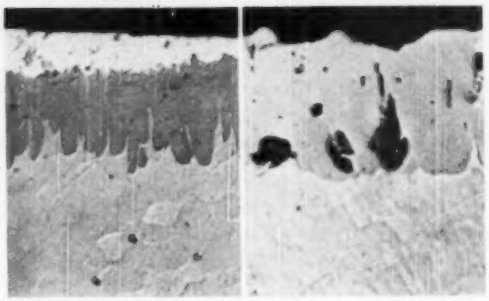


*Fig. 1 and 2 — Hot Dipped Aluminum Coating on Steel. (Left) Typical layer between coating and base. (Right) Coating completely converted to iron-aluminum compound. Both samples unetched*

If the sprayed coating is to be used for resistance to scaling, considerable benefit is obtained by applying a "sealer" such as aqueous sodium silicate or caustic solutions before heat treatment, which is generally around 1400° F. This sealer prevents diffusion of air and protects the iron from oxidation during the initial stage of heat treatment, favoring greater diffusion. Greater resistance to scaling is obtained if the steel is first sprayed with a chromium-nickel alloy, then with aluminum, and finally sealed.[14, 15] Coatings of this type have withstood several hundred hours' exposure at 1800° F. in tests at the Aluminum Research Laboratories. Spraying is the most versatile of all coating methods because it can be used on any size or shape of steel article and can be applied to large items of equipment already installed.

**Electroplating** — Aluminum is electroplated on steel by use of anhydrous electrolytes composed of fused salt mixtures of aluminum chloride with alkali chlorides[17, 18] or in organic electrolytes containing compounds such as aluminum bromide in ethyl bromide and benzol.[19, 20] It is necessary to use pure chemicals and high-purity aluminum as anode because all metallic impurities below aluminum in the electromotive series interfere with the production of a smooth, bright, adherent coating. This type of coating is free from any interfacial iron-aluminum alloy layer. An electroplated coating of aluminum on steel, obtained from a molten bath of sodium chloride and aluminum chloride, is shown in Fig. 4. The speed of plating is not so rapid as usually obtained with copper or zinc coatings, and fuming of the aluminum chloride must be controlled.

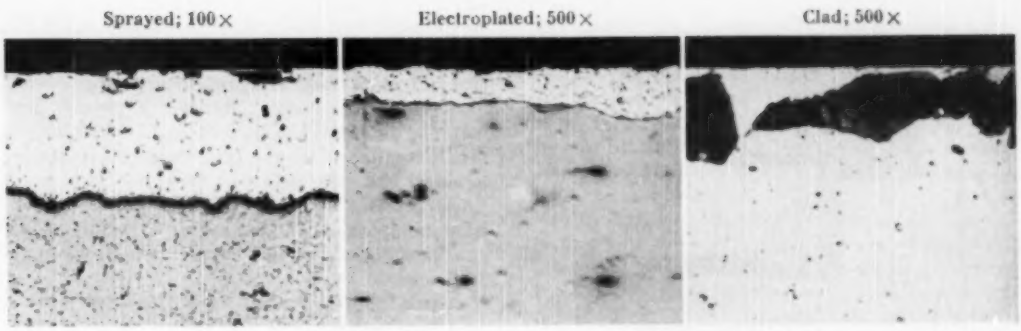


*Fig. 3 to 5 — Aluminum Coatings on Steel. Sprayed coating (left) shows oxide film and pores, no compound layer (dark zone is relief shadow). Electroplated coating (center) shows porosity and absence of interfacial layer. Clad coating (right) applied by rolling and annealing has thick, cracked iron-aluminum compound layer penetrating and even puncturing the pure aluminum surface. All unetched*

**Cladding** — Steel sheet can be clad with aluminum either hot or cold. Early attempts to bond thin sheets of the two metals together by rolling were hampered by the formation, during annealing, of the brittle interfacial layer of iron-aluminum compound which flaked, peeled, cracked and even punctured the soft aluminum coating (Fig. 5). In Germany, to overcome this obstacle, a low-carbon (0.06%) steel was used, on which aluminum sheet containing about 0.7% silicon was rolled at a temperature around 400° F. by a "sticking pass" of 40% reduction.[21, 22] Both the aluminum and steel surfaces were roughened by scratch brushing before rolling. No intermediate anneals were used and the final anneal was carefully controlled between 995 and 1020° F. to minimize the formation of interfacial layer. This was known as the Feran process in Germany.

If clean surfaces of aluminum and steel sheets are pressed together at a temperature near 1150° F. bonding occurs by diffusion (Fig. 6). This type of bonding can be accomplished at a lower temperature if the aluminum and steel are previously silver plated. Figure 7 shows an example of the silver bonding of aluminum and steel by rolling the silver plated products together at 450° F.

**Casting Aluminum Around Steel** — The bonding of aluminum to steel by casting aluminum around steel has been utilized in the Al-Fin process where steel freshly coated with aluminum-silicon alloy is quickly placed in a mold and additional aluminum is poured around the steel to fill the mold to the desired shape.[23, 24] This method is not adapted to the production of thin coatings but is used to produce massive sections of aluminum having a steel core or insert.

**Casting Iron Around Aluminum** — In a German method, aluminum wires were placed in a sand mold and were then alloyed when iron was cast into the mold.[5] An alloy containing about 10% aluminum was formed at the points where resistance to scaling was desired in the finished castings. This method, which was used for making grate bars, is limited to pure iron and is not applicable to ordinary cast iron.

**Hot Dipping** — From an operating viewpoint the lowest-cost process seems to be hot dipping, similar to galvanizing. Such a process has been developed to a commercial scale by the Armco Steel Corp., which is now producing "aluminized" sheet.[25, 26] The Armco process is reported to involve pretreating the steel in a controlled atmosphere before it enters the aluminum bath.[27] Other

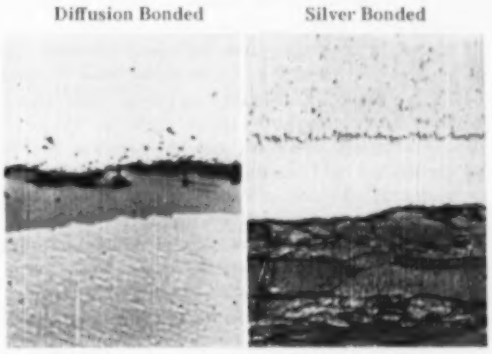


*Fig. 6 and 7 — Aluminum Bonded to Steel by Heat and Pressure. (Left) Aluminum bonded directly by 10,000 psi. pressure for 7.5 min. at 1150° F.; note uniform interfacial layer; dark zone is relief shadow. (Right) Silver plated sheets rolled together at 450° F.; central white zone is silver; note lack of compound layer. Both unetched; 500 ×*

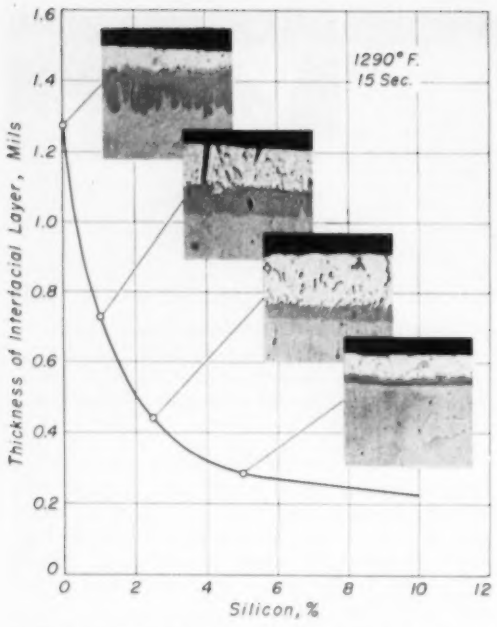


*Fig. 8 — Effect of Silicon on the Formation of Iron-Aluminum Interfacial Layer. Micros at 250 ×*

hot dip processes are similar to hot dip galvanizing in using a pickle followed by molten flux, after which the steel enters the molten aluminum bath.

In applying an aluminum coating by hot dipping it is desirable to hold the brittle interfacial layer to a minimum thickness in order to permit bending and forming of the coated products. One of the most effective means for accomplishing this is by addition of silicon to the aluminum coating bath. As the silicon content increases up to about 2.5% there is a rapid decrease in the thickness of this interfacial layer. A smaller decrease occurs as the silicon content is further increased (Fig. 8).

Another important factor is the temperature of the coating bath; as the temperature increases, a thicker interfacial layer forms, both for pure aluminum and the 5% silicon alloy (Fig. 9). A wider range of temperature can be tolerated in a commercial coating process using the silicon alloy.

Figure 10 shows a coating consisting entirely of iron-aluminum compound, formed at a temperature of 1650° F. This type of coating, obtained either by hot dipping at a high temperature or by heat treating various kinds of coatings, is often desired for resistance to scaling.

In a typical hot dip coating process the flux bath is maintained around 700° F. and the aluminum-silicon alloy bath around 1250° F., which is high enough to cause some softening of steel. Table I shows the effect of the hot dip coating process on the tensile strength of several steel wires of different carbon contents. The cold drawn wire is softened by the high-temperature coating process, but the patented wire was not much affected. The Aluminum Co. is trying the use of aluminum coated high-carbon steel wire to replace the galvanized core wire in aluminum electrical transmission cable.

A hot dipped coating 1 mil thick corresponds to a coating weight of 0.50 oz. per sq.ft. of sheet (both sides coated), in comparison with a coating weight of about 1.30 oz. of zinc for the same thickness of galvanized coating.

**Coating of Cast Iron** — It is more difficult to produce a satisfactory aluminum coating on cast

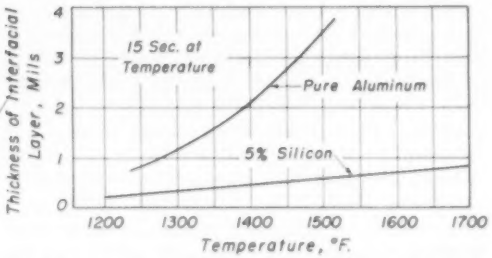


*Fig. 9 — Effect of Temperature of Coating Bath on Formation of Iron-Aluminum Interfacial Layer*

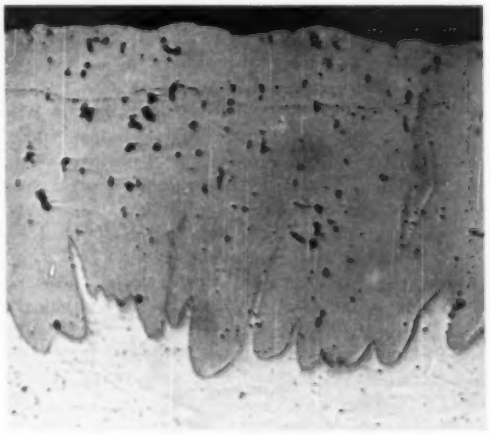

*Fig. 10 — Coating Obtained by Hot Dipping Steel in Pure Aluminum at 1650° F. Note absence of any pure aluminum surface layer and complete conversion of coating to iron-aluminum compound. Unetched; 500 ×*

**Table I — Effect of Hot Dip Aluminum Coating on Tensile Strength of 0.064-In. Steel Wires**

| Steel | Before Coating | After Coating |
|---|---|---|
| 0.10% C, cold drawn | 130,000 psi. | 80,000 psi. |
| 0.45% C, cold drawn | 180,000 | 130,000 |
| 0.75% C, cold drawn | 275,000 | 200,000 |
| 0.45% C, air patented | 108,000 | 105,000 |
| 0.75% C, air patented | 164,000 | 162,000 |

iron than on steel. This is not surprising; it is well known that cast-iron melting pots are not attacked by aluminum to the extent that steel pots are attacked. This difference is true for either hot dipped or sprayed coatings. Some improvement can be obtained by decarburizing the surface layer of the cast iron or by using a preliminary sprayed coating of pure iron.

## Containers

In any continuous coating process there is a problem of iron contamination in the aluminum bath; the iron content will gradually increase to about 1.5%, where a sludge is formed. Usually this sludge settles out, but if there is sufficient agitation it will be suspended in the bath and will cause a rough coating. This amount of iron does not seriously diminish the protective qualities of the coating, although hard particles of the iron constituent may be trapped therein.

Refractory containers are more economical for holding aluminum if a suitable method of heating can be found. The heating can be accomplished by passing an electric current through the fused salt on which the molten aluminum floats.[28] The proposed Moeller process employs such a furnace, in which the molten salt used for heating is also used for the fluxing pretreatment of the articles, which are immersed through the aluminum into the flux and back up into the aluminum layer.[29]

## Selection of Process

Table II rates those factors which are important in the selection of a process for aluminum coating of steel products. A rating of 1 indicates the best classification.

The amount of heating involved is important and must be defined for this classification in order to evaluate the formation of the iron-aluminum compound layer. Since the chemical reaction process is carried out at a high temperature, no aluminum coating (only the compound) is obtained. Any cladding process is assumed to include annealing or hot rolling, and hot dipping involves heating the aluminum above the melting point, to form a bath.

The coating thicknesses given are typical ranges obtained from measurements of numerous samples. The iron-aluminum alloy coating obtained by chemical reaction is too thin to have much value. For corrosion protection, an aluminum coating thickness of at least 1 mil is desirable; 3 mils is better. The absence of the interfacial layer is desired for bending or subsequent rolling operations. Unfortunately, the electroplated and sprayed coatings, which have no interfacial layer, are the most porous of all.

The cost rating is based on similarity to known operations in galvanizing and to some extent on cost prices quoted for commercial jobs involving spray coating and calorizing. Eventually, hot dipping, cladding or electroplating would probably be conducted as continuous operations, similar to processes now used for other metal combinations.

**Table II — Comparison of Processes for Aluminum Coating of Steel**
A rating of 1 indicates the best classification

| Process | Thickness of Coating, mils | Absence of Interfacial Layer | Continuity of Aluminum Coating | Cost Rating |
|---|---|---|---|---|
| Hot Dipping | 0.5 - 3.0 | 2 | 2 | 1 |
| Cladding | 0.4 - 5.0 | 3 | 1 | 2 |
| Electroplating | 0.1 - 2.0 | 1 | 3 | 3 |
| Spraying | 2.0 -20.0 | 1 | 4 | 4 |
| Chemical Reaction | 0.05- 0.1 | 4 | — | 3 |
| Calorizing* | 10.0 -40.0 | 4 | — | 3 |

*Includes all coatings that are heat treated for impregnation.

## Conclusion

The aluminum coating of iron and steel product is feasible. However, some further effort is required on the development of operating details to enable aluminum coated steel to take its proper position among coated metal products.

## References

1. "Resistance of Iron-Aluminum Alloys to Oxidation at High Temperatures", by N. A. Ziegler, *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 100, 1932, p. 267.

2. "Heat Resistance of Aluminum Steels and Alu-
*(References continued on p. 128)*

# Infiltration of Powder Metal Compacts With Liquid Metal

**By Paul Schwarzkopf**
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*There are two ways of producing useful objects from powders of metals that are only slightly soluble in each other. One is to mix the powders, press them and sinter at a temperature high enough to melt the lower-melting metal. In the other method, the high-melting metal is first pressed to form a porous compact, and then the lower-melting metal is "infiltrated" as liquid into the pores of this skeleton. The author discusses products made by infiltration, with particular emphasis on the structure and properties of iron-copper mixtures.*

THE ARCHAEOLOGIST is kind to our prehistoric colleagues. He reports only their successes, not their failures. Accordingly, we do not know whether or not one of the early metallurgists ever tried to infiltrate iron sponge with liquid copper or bronze. This possibility is not fantastic, since the furnaces at the disposal of prehistoric engineers permitted the melting of copper and bronze but did not attain the temperatures required for the melting of iron. As there is no evidence of ancient infiltration procedures, it is necessary to jump some six thousand years from prehistoric cultures to the renaissance of powder metallurgy in the second decade of the present century.

Here we first meet infiltration processes in the patent literature. Applications of Friedrich (German patent application 36,132; 1913) and Leiser (British patent 148,533; 1914) describe the principles of the infiltration process. It is worth noting that this process was invented earlier than the sintering of powder mixtures in the presence of a liquid phase. It was not until 1916 that Gebauer applied for his basic patent (U. S. 1,223,322; 1917) on sintering cold pressed powder mixtures in the presence of a liquid phase. In this patent, Gebauer clearly formulated one of the main advantages of composite materials, namely, that of combinations of unalloyable metals which can be produced only by his process or by infiltration. Gebauer specifically states: "The component metals shall be integrally welded together while preserving their nonhomogeneous character, with the result that the finished product has the physical properties of the component elements and not a different set of properties as would be the case with an alloy."

One of the earliest and commercially most important practical applications, until recently, for composite materials was heavy-duty contact and electrode material, which had to combine high electrical conductivity with properties such as high wear resistance or resistance to mechanical deformation under pressure, a combination not found to the required extent in homogeneous materials. The first of these requirements is met by the refractory metals tungsten and molybdenum, and the second by the lower-melting metals silver and copper. Satisfactory contact and electrode materials were — and are — prepared on a commercial scale by infiltrating skeletons of wear resistant refractory metals with the lower-melting and better-conducting metals of the second class. The same composite materials were — and are — also produced by sintering the appropriate powder mixtures at a temperature corresponding to that of infiltration, that is, at a temperature below the melting point of the higher-melting and above the melting point of the lower-melting powder constituent. According to Smithell's

book "Tungsten" (Chapman & Hall, 1936, p. 217), tungsten-copper products prepared by infiltration are somewhat harder than those produced by sintering powder mixtures in the presence of a liquid phase.

## Early Successes and Failures

The development of these composite contact and electrode materials — the first successful practical application of the infiltration process — took place in the early twenties. About at the same time (1922), Baumhauer applied for a patent for his method of producing tool materials by infiltrating tungsten carbide with molten metals such as iron (U. S. patent 1,512,191; 1924). This patent resulted in a serious setback for the infiltration method, for Baumhauer did not succeed in manufacturing satisfactory tool materials by his method. On the other hand, Schroeter succeeded in producing such materials by sintering powder mixtures of tungsten carbide and binder metals of the iron group (German patents 420,689 and 434,527, 1923 and 1925; U. S. patent 1,549,615, granted 1925, invalidated 1940). The mixtures were sintered between the melting points of tungsten carbide and the binder metal.

Here was an example where sintering in the presence of a liquid phase proved superior to the infiltration method. The infiltration method was tabled because of this unfortunate occurrence, and I daresay that without the unlucky experiments of Baumhauer, the infiltration method would have found other applications earlier than it actually did. As it was, the infiltration method needed almost two decades to live down this setback. At present it appears uncertain whether the failure of Baumhauer was due to a principal disadvantage of the infiltration process (as compared with the Schroeter procedure) or whether it was due to the fact that Baumhauer did not use the most favorable experimental conditions for his infiltration experiments. It must be remembered that the iron-copper system is specifically mentioned in the first patent applications of Friedrich and of Leiser. Copper-infiltrated iron products were thus known before the first World War. Nevertheless, it took a third of a century to develop, through improved infiltration techniques, modern infiltrated iron and steel products.

## Steps in the Production Process

As long as the combination of different characteristics is the primary aim, sintering of mixed powders in the presence of a liquid phase is more or less equivalent to the infiltration technique. However, if optimum values of mechanical properties are the goal — as they are for copper-iron products — then the infiltration method becomes definitely superior.

To a large extent, this superiority of the infiltration technique may be attributed to the higher density of the infiltrated products. There are, however, other contributing factors, some of which were unknown to us when we started our development program.

The principal steps of the production process are: *(a)* compacting iron powder to the desired shape, *(b)* sintering the iron skeleton, *(c)* infiltrating the iron skeleton with a liquid copper alloy, and *(d)* cooling and heat treating the infiltrated skeleton. Intermediate or final coining operations, which may be required to insure dimensional accuracy, as well as special finishing treatments, may be added.

The first two steps are standard operations of powder metallurgy. Pressure and temperature conditions are selected to yield a skeleton that can readily be infiltrated. What are the requirements for a readily infiltrated skeleton? Obviously, density specifications will not suffice, since the pore diameter and the extent of interconnection of the pore system will be decisive factors. It would be expected that capillaries of small diameter would be more readily filled than large diameters. However, in some instances, the flow resistivity will reverse the relationship. Neither the interfacial tensions involved, nor their changes by mutual solubility, are known. It is impossible to describe the pore structure by a simple mathematical function, and the situation is further complicated by the fact that the pore structure changes during the infiltration process by progressive sintering of the skeleton. In view of these difficulties, it is not surprising that a theoretical prediction of the most favorable skeleton structure is impossible. The structure that permits the most satisfactory infiltration must be found empirically for any given system.

As long as we are concerned with simple shapes such as cylinders or rectangular bars, the optimum skeleton structure can be established by a few experimental runs. But how about parts of complicated design, particularly parts with widely varying thickness which do not permit compaction to approximately uniform density distribution? Obviously, it will not be possible to realize optimum conditions for the thick as well as the thin portions of the piece. This seemed to introduce a serious difficulty, but our experiments demonstrated that — at least as far as the effects on the strength of the final parts were concerned — this difficulty had been overestimated.

## Effect of Density on Properties

According to the unpublished experimental work of G. Stern, a skeleton may have portions differing as widely in density as from 65 to 90%; but after infiltration the strength of the different portions will be practically identical. This equalization of strength values is much more pronounced than the corresponding equalization of densities effected by the filling of the pores. In order to understand fully the effect observed we must consider that the extent of infiltration will not be the same in different portions of the skeleton. The densest portions will have pores that are not interconnected with each other and with the surface, and will therefore not be filled during infiltration; the most porous portions will be completely infiltrated; and portions of intermediate porosities will exhibit intermediate degrees of infiltration. What is the consequence of this residual porosity in the densest parts of the compact? As far as the density is concerned, residual porosity will counteract the equalization. Copper has a higher specific gravity than iron. The portions containing most of the copper will therefore show the highest specific weight. This difference will be increased by the presence of unfilled pores in the high-iron portions. This relationship is, however, reversed when we consider the mechanical strength. Iron is stronger than copper, and the high-iron portions should therefore exhibit the highest mechanical strength. The presence of pores in these portions keeps the strength down, and thus produces the far-reaching equalization observed. This effect is illustrated by the results shown in Fig. 1.

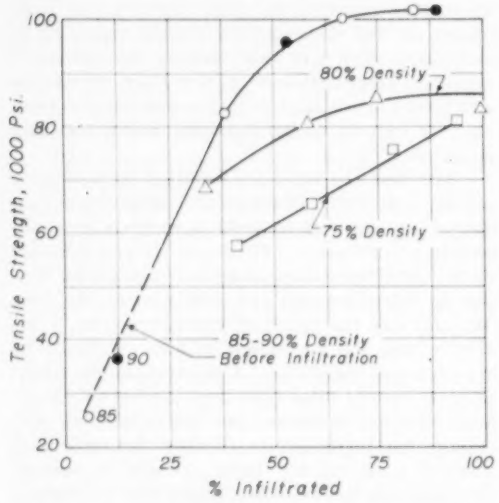


*Fig. 1 — Effects of Percentage Infiltration and Density on Tensile Strength of Copper-Infiltrated Iron. Note that a tensile strength of 80,000 psi. is obtained with three different combinations of density and infiltration*

## Sintering After Infiltration

The third step of our production cycle is that of infiltrating the iron skeleton with a liquid copper alloy. Since the temperature at which infiltration takes place is sufficient for the sintering of iron, further sintering of the iron skeleton will therefore continue during the infiltration step. The filling of the pores with the infiltrant is completed in seconds or, at most, a few minutes. But experience has shown that the charge must be kept at infiltration temperature for a considerably longer time to insure optimum properties. We are, therefore, justified in distinguishing between infiltration proper and the subsequent period during which the infiltrated charge is kept at temperature. This latter period may be considered as a sintering step in the presence of a liquid phase. From this viewpoint, we may describe the infiltration process as a sequence of three steps: *(a)* sintering in the absence of a liquid phase, *(b)* infiltration, and *(c)* sintering in the presence of a liquid phase.

This may be more than just a novel way of describing the infiltration process. There may be distinctive advantages in first sintering in the absence, and subsequently in the presence, of a liquid phase. We know that when we sinter pure iron, the pores tend to assume spherical shape. This effect of the surface forces will become pronounced only after long sintering times at high sintering temperatures, but the tendency will always be there. When, on the other hand, iron is sintered in the presence of a copper-rich liquid, the iron particles will tend to assume spherical shape. The tendency prevailing in the first case (iron) is shown schematically in Fig. 2. Spheroidization of pores is accompanied by the establishment of large contact areas — with concomitant strong bonding — between the iron particles. In the second case (iron plus copper), the spheroidization of the iron phase counteracts the establishment of large contact areas — that is, strong bonds — between the iron particles, as indicated in Fig. 3.

When sintering first in the absence, and subsequently in the presence, of a liquid phase, the contact areas established during the first step will not be reduced in size during the following treatment, and a structure as indicated in Fig. 4 will be

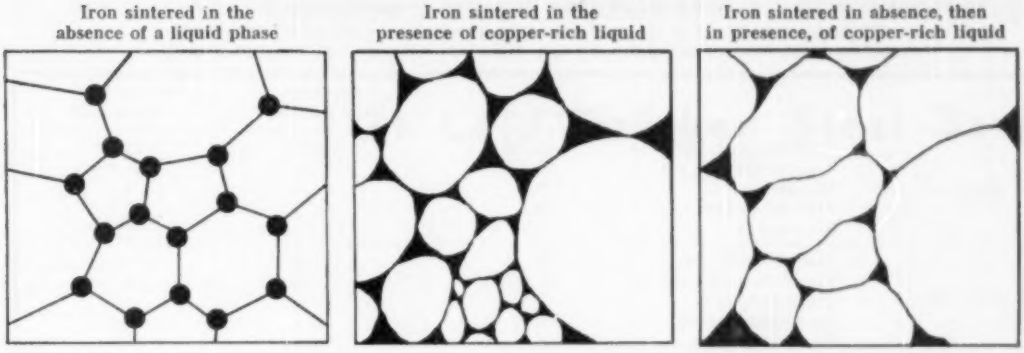
Iron sintered in the absence of a liquid phase
Iron sintered in the presence of copper-rich liquid
Iron sintered in absence, then in presence, of copper-rich liquid

*Fig. 2 to 4 — Effect of Sintering Method on the Structure of Powder Metal Compacts (Schematic)*

favored. The sequence thus offers the possibility of combining the advantageous formation of large iron-to-iron contact areas with the benefits of sintering in the presence of a liquid phase. Figure 5 shows the microstructure of a copper-infiltrated iron, magnified 100 diameters.

Prerequisite for successful infiltration is obviously a good wetting of the skeleton by the infiltrant. The wetting performance is determined by the interfacial tensions involved, and these, in turn, vary with the chemical composition of the copper and iron phases. Since the interfacial tensions cannot be measured, the most favorable infiltrant composition must be found by trial and error. For practical purposes, it seems justifiable to assume that the composition showing the best wetting action represents the best infiltrant. However, C. S. Smith has convincingly demonstrated that a

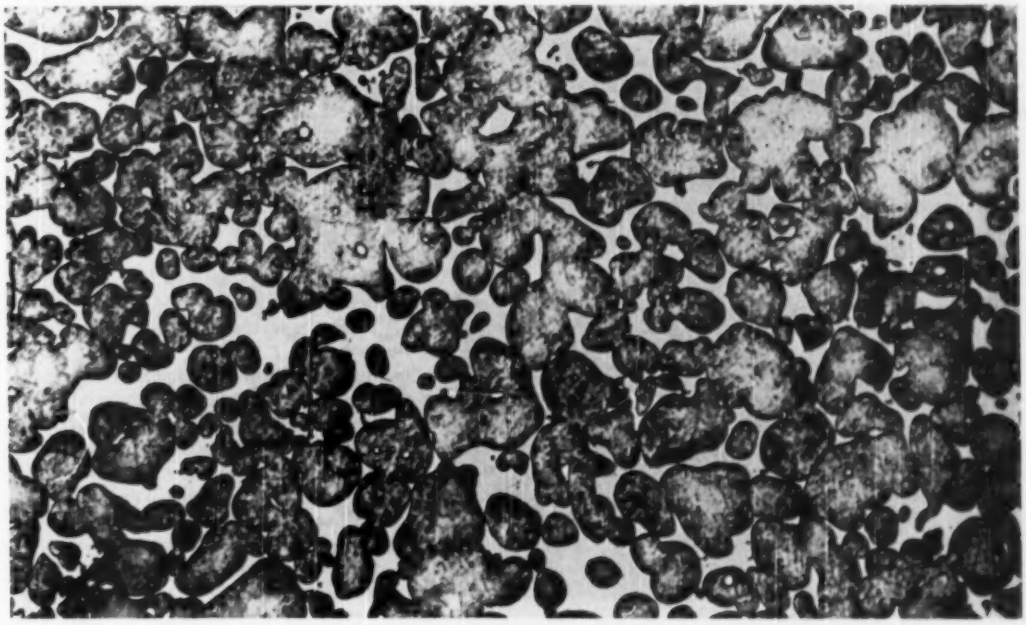

*Fig. 5—Microstructure of Copper-Infiltrated Iron. The ferrous skeleton was pressed, sintered to 85% density, and then completely infiltrated with a liquid containing 90% Cu, 2% Fe, 8% Mn. 100×*

**Table I — Effect of Heat Treatment on Some Mechanical Properties of Infiltrated Iron and Steel**

The ferrous skeletons of all specimens were pressed and sintered to 85% density. Complete infiltration of all specimens then left them virtually free from residual pores.

| | | As Infiltrated§ | Solution Heat Treated* | Precipitation Hardened¶ |
|---|---|---|---|---|
| Fe-Cu* | Yield Strength, psi. | 61,200 | 61,300 | 75,400 |
| | Tensile Strength, psi. | 67,500 | 71,700 | 81,900 |
| | Elongation, % | 3.3 | 6 | 3 |
| | Area Reduction, % | 3.3 | 6.6 | 3.5 |
| | Rockwell B | 95.5 | 82 | 92.5 |
| Fe-Cu-Mn† | Yield Strength, psi. | 89,500 | 70,500 | 87,100 |
| | Tensile Strength, psi. | 91,800 | 84,600 | 93,500 |
| | Elongation, % | 1.3 | 5.3 | 2.6 |
| | Area Reduction, % | 0.82 | 7.0 | 2.4 |
| | Rockwell B | 96.5 | 89 | 91.5 |
| Fe-Cu-C‡ | Yield Strength, psi. | 72,900 | 71,300 | 78,500 |
| | Tensile Strength, psi. | 76,100 | 76,700 | 79,500 |
| | Elongation, % | 1.6 | 3.0 | 2.3 |
| | Area Reduction, % | 2.1 | 6.0 | 3.8 |
| | Rockwell B | 88 | 101 | 89.5 |
| Fe-Cu-C-Mn†‡ | Yield Strength, psi. | 95,200 | 88,500 | 93,900 |
| | Tensile Strength, psi. | 95,200 | 92,900 | 94,700 |
| | Elongation, % | 1.3 | 2 | 1 |
| | Area Reduction, % | 0.82 | 1.63 | 0.82 |
| | Rockwell B | 96 | 94.5 | 91.5 |

*After pressing and sintering to 85% density, specimens were infiltrated with a mixture containing 98% electrolytic copper and 2% iron. †The infiltrant was a mixture of 90% copper, 2% iron and 8% manganese. ‡Graphite (0.25%) was added to the iron powder prior to compaction. §Infiltrated at 2125° F. for 1 hr. •The infiltrated specimens were heated to 1300° F. for ½ hr., and then to 1600° F. for ½ hr., and finally quenched in oil. ¶After solution heat treatment, the specimens were precipitation hardened by holding at 930° F. for 1 hr.

contact angle of zero — that is, the best possible wetting — can be expected to have rather disastrous effects in the case of copper-infiltrated iron (*Transactions*, A.I.M.E., Vol. 175, 1948, p. 15). The mutual solubility of iron and copper would finally lead to a complete intergranular disintegration of the material. In our work, we have been lucky enough so far not to find an infiltrant that has such good wetting properties that our product disintegrated. For practical purposes it seems justifiable, therefore, to consider good wetting properties as an indication of satisfactory infiltration.

## Heat Treatment of Copper-Iron

The last step of the process — the heat treatment of the infiltrated material — produces the outstanding physical characteristics which are the basis for the most important practical applications of "copper-cemented" iron and steel. The heating and cooling cycle must be designed to effect precipitation hardening in the iron-rich as well as in the copper-rich phase, and must take into consideration the exact composition of both. This refers, of course, not to the initial composition but to the composition after infiltration. The infiltrant can be used also for the introduction of alloying elements into the ferrous skeleton. If this is done, the distribution of these alloying elements between the two phases must be taken into account when designing the hardening cycle. The improvements in properties which can be achieved by heat treatment are illustrated by the data listed in Table I, which have been extracted from the unpublished work of G. Stern.

It is perhaps worth mentioning that the results quoted by Stern are not restricted to laboratory specimens. These are values actually reached in mass production.

The use of infiltration techniques for the production of high-strength structural materials is a comparatively new development. Infiltration represents the most economical method for producing a pore-free material by powder metallurgy. We believe that infiltration techniques will find wider applications rather soon. One of the next steps will probably be the development of corrosion resistant materials by combining corrosion resistant copper alloys with skeleton materials of the stainless steel type. The applicability of improved techniques of infiltration is by no means limited to ferrous skeletons and cuprous infiltrants.

# Continuous Induction Hardening of Cold Finished Steel Bars

**By J. J. Day, Jr.**
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*Perhaps the most common use of induction heat treatment is in producing shallow hardened cases on steel products. The main application discussed here is for full cross sectional hardening of bar stock — that is, hardening as deeply as the hardenability of the steel will permit. Soft centers can be produced by suitable control of the power input and the rate of travel of the bar in this process. The author compares results of continuous induction hardening with those obtained by conventional heating and water quenching.*

THE PROCESS of full cross sectional hardening by means of continuous induction heating and water quenching was developed by the Ohio Crankshaft Co. and first used on a production basis by the Caterpillar Tractor Co. at Peoria, Ill. It was found to be superior to conventional furnace heating and quenching in producing over-all uniformity of mechanical properties. The induction heat treating unit described here is the first to be installed by a steel manufacturer to heat treat cold finished bars to specific hardnesses and mechanical properties as a regular production item.

**Equipment** — In the "Electreat" process used by the Jones & Laughlin Steel Corp., the high frequency power for induction heating is derived from a "Tocco", 9600-cycle, 125-kw. motor generator. As shown in Fig. 1, each production line has two inductor coils set in tandem, especially designed for maximum penetration of heat. These inductor coils are of the multiturn type using 12 to 22 wraps, depending on the diameter of the coil. This type of coil distributes the power over a relatively large surface area, which prolongs the heating cycle sufficiently for penetration of heat throughout the cross section of the bar. Currently four sets of coils are being used (¾, 1, 1½ and 2 in.), which permit

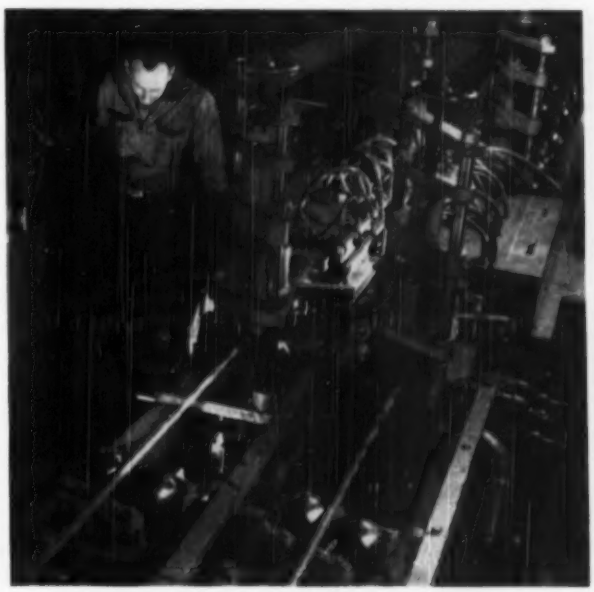


*Fig. 1 — Continuous Induction Heat Treating Installation Consisting of Two Parallel and Similar Production Lines*

the heat treatment of bar sizes ranging from ½ to 2 in. in diameter. The first coil preheats the bar to temperatures from 900 to 1200° F.; the second coil heats the bar to quenching temperature, from 1500 to 1750° F. A high pressure conical water spray quenching unit for continuously quenching the bars is closely coupled behind the second inductor coil. Individually driven bar conveyer rollers with pinch rolls placed at the entrance to the first coil and behind the spray unit assure a positive rate of speed of the bar in process. The installation also incorporates special mechanical features for automatically handling and actuating the bars through the coils and quenching unit in a uniform, continuous manner. Once the required power input and the rate of feed are established for an item, the bars may be fed continuously and the resulting hardness will be uniform from bar to bar.

The unit was originally designed for round bars only, in sizes ranging from ½ to 1 in. in diameter, with a special type of conveyer roller for rotating the bars as they passed through the inductor coils and quenching unit. To accommodate hexagonal and square sections, which could not be rotated, necessitated a change to straight rollers. Design changes have also increased the capacity of the unit so that rounds, squares, and hexagons from ½ to 2 in. cross section may be handled in 10 to 24-ft. lengths. Production rate varies with respect to bar size and metallurgical requirements, averaging about 500 lb. per hr. for each line.

## Metallurgical Factors

In the initial stages of development, it was fully realized that the acceptability of the induction hardened product depended primarily on the ability to develop quenched structures and mechanical properties comparable in every respect to those obtained from conventional heating and quenching. The induction heat treating process herein described does not attempt to produce the shallow hardened cases common to high-frequency induction heat treating, but rather full cross sectional hardness within the limits of the hardenability of the steel being treated. It is possible to control the depth of hardness to some extent, however, and this is done in cases where subsequent processing involves removal of the bar center, such as cylindrical parts and nut products where the hardness is required only through the wall of the finished part. Easier machining of the bar interior is thus attained without sacrificing the mechanical properties of the finished part.

**Cross Sectional Hardness** — A thorough study of hardened microstructures and mechanical properties was made to determine the ability of this method to produce the desired heat treated properties. Figure 2 shows the results obtained on a 1-in. round, C1045 steel, induction heat treated bar, compared with results obtained by conventional heating and water quenching in the laboratory. Average quenched hardness for this grade after

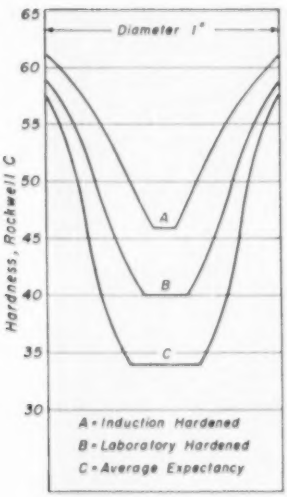



*Fig. 2 — Hardness of 1045 Treated by Conventional and Induction Methods*

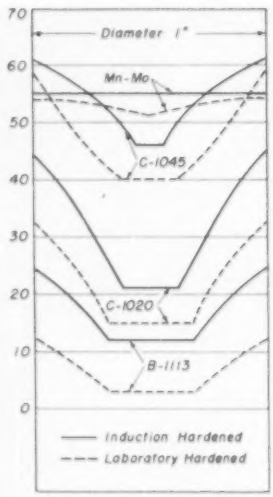



*Fig. 3 — Comparative Hardnesses of Four Fully Hardened Steels*

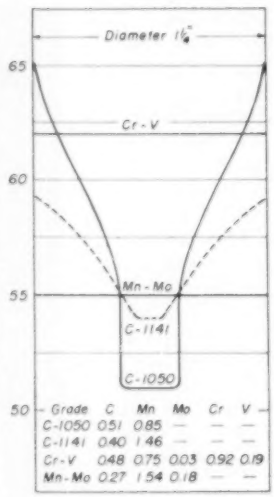



*Fig. 4 — Hardenability Characteristics of Four Induction Hardened Steels*

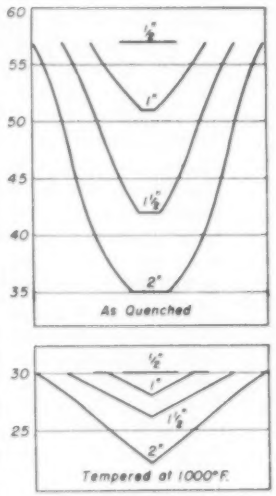



*Fig. 5 — Effect of Bar Size on Hardness of Type 1141 Steel*

normal shop heat treatment is also included, as curve *C*, for further comparison.

The higher hardness shown for the induction hardened product is attributed to the method of quenching, although, in general, a finer martensitic structure is obtained from the relatively short induction heating cycle than from conventional heating. Another factor in promoting greater surface hardness and penetration is the absence of scale and decarburization from the bar surface, also a result of the short heating cycle.

Further evidence that the induction hardened product is superior to that of conventional heat treatment is shown in Fig. 3. Here samples 7 in. long were cut from cold finished bars of four types of steel having widely varying hardenability characteristics. The samples were furnace heated and water quenched under controlled laboratory practice and the results obtained are therefore indicative of better than average production expectancies. The remainder of the bars from which the 7-in. samples were cut were induction heat treated. It will be noted that the comparative results show a distinct advantage for the induction process and particularly with respect to the low hardening C1020 and B1113 grades which are not normally hardened but are shown to illustrate the effectiveness of this method of heat treatment.

Effect of the type of steel in developing heat treated end products is shown in Fig. 4. In general, induction heat treatment develops the maximum surface and depth of hardness to be expected for the grades involved. The two alloy steels, chromium-vanadium and manganese-molybdenum, were included to show that the relatively short induction heating cycle permits the formation of austenite of satisfactory composition for hardening, even for these grades in which homogenization of austenite is rather sluggish as compared to plain carbon grades. Cross sectional uniformity was obtained on both, despite widely varying carbon contents.

Figure 5 shows the influence of bar size on cross sectional hardness of C1141 produced by induction heat treating. Hardness was measured both in the as-quenched state and after tempering at 1000° F. Surface hardness is uniform throughout all sizes and is maintained along the length of the bars. The hardness gradient from surface to center is an index of the hardenability of the grade.

**Depth of Hardening** — This is controlled by employing the full power input to obtain maximum speed of surface heating, and varying the rate of feed of the bars. Figure 6 illustrates the results

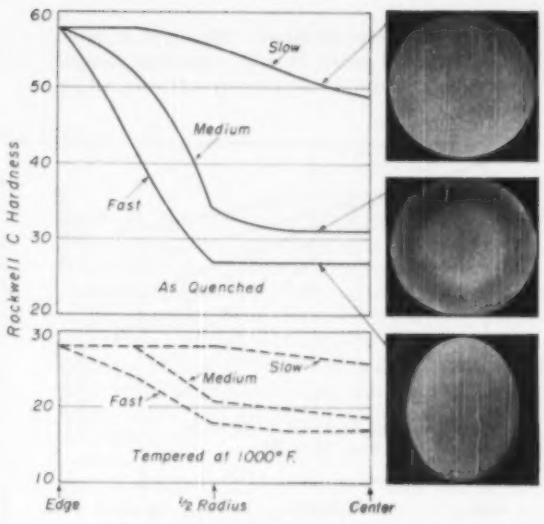



*Fig. 6 — Depths of Hardening of C1040 Obtained by Controlling the Rate of Feed. Table below shows tensile properties*

| Induction Hardening Cycle | Tensile Properties After Tempering at 1000° F. | | | |
|---|---|---|---|---|
| | Yield Point | Tensile Strength | Elongation, % in 2 In. | Reduction of Area, % |
| Slow | 112,800 | 127,500 | 18.5 | 53 |
| Medium | 95,200 | 117,800 | 21.0 | 54 |
| Fast | 81,300 | 109,600 | 22.5 | 56 |

obtained with slow, medium and fast heating rates. Notice the rather sharp line of transition from hard to soft structure in the macrograph of a fast heated bar, a more gradual transition in the medium, and its complete absence in the slowly heated bar.

Cross sectional hardness comparisons of these structures as quenched and after being tempered at 1000° F. are also shown in Fig. 6. Surface hardness is the same on both fully hardened and shallow hardened stock, but the center hardness of the former tempered at 1000° F. is the same as the latter as-quenched. The ability to maintain maximum surface hardness is a characteristic advantage of induction heat treating, especially when used in connection with scale-free cold drawn bars. Mechanical properties obtained from tensile tests on 0.505-in. standard 2-in. gage-length C1040, heat treated at slow, medium, and fast speeds and tempered at 1000° F., are given in the table below Fig. 6.

In the manufacture of heat treated nuts, hexagonal bar stock, furnished as-drawn, is usually specified in one of the resulphurized grades C1137 or C1141, in order to produce better machinability

on automatic screw machines. This type of product is hardened using closely controlled heating rates so as to maintain a relatively soft core, which

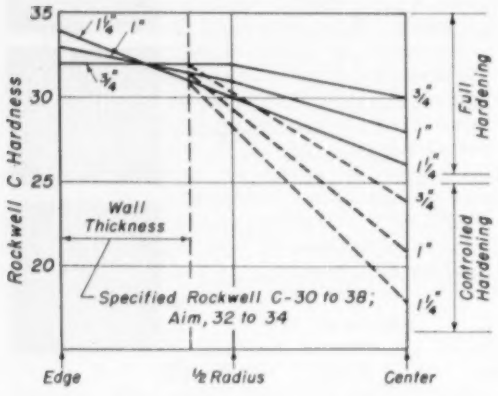



*Fig. 7 — Typical Controlled-Depth Induction Hardening Practice Applied to Hexagonal Bar Stock, C1141 Grade, as Compared With Full Cross Sectional Hardening. Controlled hardening gives desired wall strength and leaves core soft for machining*

is much easier to machine. Figure 7 shows results on C1141 steel for ¾, 1, and 1¼-in. hexagonal stock, both by full and controlled hardening practice. Controlled practice gives satisfactory wall hardness with a soft, machinable core.

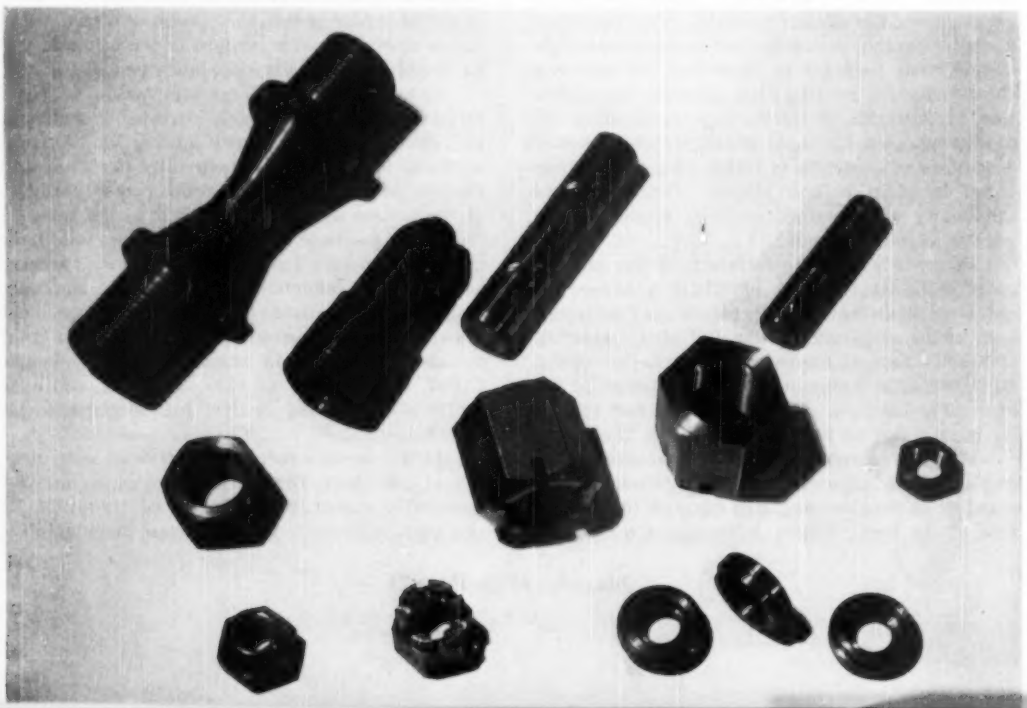
## Summary


The continuous induction method of heat treating cold finished steel bars produces scale-free products of superior hardness and uniformity of mechanical properties. The method is also flexible so that hardness penetration can be controlled to produce relatively soft cores when subsequent processing involves center removal by machining or drilling.

The process eliminates the heat treatment of finished parts and the resultant distortion and volume changes frequently encountered. By producing parts from induction heat treated stock the extra machining and sizing operations employed to correct for distortion, volume changes and scale-pitted surfaces are eliminated. It is also possible to order the cold finished induction treated stock closer to the size of finished parts, which permits more parts per ton of steel.

Numerous types of end products are being fabricated from induction heat treated bar stock such as special axles and shafts, fuel pump shafts, studs, engine stud bolts, connecting rod nuts, cylindrical parts, hoisting adjusting screws, and pin stock. Figure 8 shows a few typical parts that illustrate the machining operations carried out on induction heat treated bar stock.


*Fig. 8 — Typical Parts Machined From Induction Heat Treated Bar Stock*



# Critical Points

## By the Editor

AT THE CLEVELAND plant of National Bronze and Aluminum Foundry Co., metallurgist EDMUND WAECHTER demonstrated the possibilities of their "Perfecast" for precision casting large and intricate pieces of difficult alloys to extraordinarily close tolerances. Probably the most surprising were tapered hobs for cutting internal threads on drill-pipe joints, a conical tool 4 in. in base diameter, 5 in. high, cast in a cobalt-base alloy of the "Stellite" family, usable as-cast (except for shot blasting and grinding along the leading edges of the flutes) at surface speeds of 350 to 400 ft. per min. Contours of the threads on this hob are checked to 0.0001 in. by optical comparator. Other unusually large pieces weighed up to 40 lb., with over-all dimensions of 18 to 24 in. Dimensional accuracy of such large parts derives from patterns of solid mercury, frozen in sectionalized steel dies. Various portions of intricate patterns may be frozen in individual molds, assembled while still in the mold, and feeding heads attached by merely placing mating surfaces of bare mercury in contact. All this is done at temperatures well below −39° F., the freezing point of mercury, where the metal is quite rigid; such rigidity is obviously a prime reason for retaining the close tolerances built into the molding dies clear through to the final casting. After the steel die is removed the mercury pattern is dipped two or three times in a fine refractory suspended in frigid acetone, and then plastered with a coarser strong refractory to a thickness of about $\frac{3}{16}$ in. This work is also done in an oversized "deep freeze" cooled by dry ice. Actual freezing of mercury is by a bath of acetone (freezing point −135° F., boiling point +135° F., a most useful range), cooled by dry ice at −110° F. . . . . Once this jacket of refractory sets, the mold is removed to the open air, the mercury quickly melts, and the remaining shell is baked to set the binder and remove traces of solvent. It is now quite rigid, and is merely baked in a steel flask and surrounded by loose sand, then preheated to proper degree and poured. WAECHTER emphasized that the casting's quality and soundness are due not only to metallurgical control of the alloy, induction melted, but also to the properties of this thin mold — smooth, almost porcelanic to the touch on inner surfaces, yet porous enough to absorb minor entrapments of air. Likewise it has a certain degree of heat conductivity; its thickness can be varied and its degree of preheat regulated so the cooling rate of the casting can be adjusted within useful limits. One of the items in production are intricate valve bodies of stainless steel with walls ⅛ in. thick, that must be radiographically sound and withstand a 500-psi. hydraulic pressure test.

**Unusual precision castings**

ROCKFORD (a city of 110,000 in northern Illinois, abandoned by railroads, to judge by the passenger schedules) was once an important center for furniture manufacture. In those days National Lock Co. started making hinges, locks, drawer pulls, screws and similar items of furniture hardware. It still does, and the contrast between Victorian designs, ornate and bronzy, and today's smooth combinations of steel, chromium and plastic is curious and revealing. Much hardware now goes to makers of refrigerator cabinets and stoves, although an extraordinary amount is sold through retail stores to individual householders who want to doll-up the old place. For example, 40,000,000 drawer pulls of one simple, clean design have been made! Screws and bolts by the billion are matters, of course. Their astronomical production was recently reflected in a 3-week delivery of 8,000,000 truss-head bolts for corn cribs (you've heard of Uncle Sam's price support program), $\frac{5}{16}$ by ¾ in. long, cadmium plated, each with a loosely held lead washer. . . . . Dies of all sorts for heading, blanking, forming, die casting, plastic molding, are a principal item of toolroom production. FREEMAN ANDERSON, chief metallurgist, said that punches for sinking the cross-shaped slots in a "Phillips head" screw are in particularly rugged service, and they gather a lot of frictional heat and must be made of high speed analyses. Likewise they are a difficult shape to machine, so the conformations are pressed into warm "Motung" steel from a master die. ("Hobbing", "hubbing", or "typing" are words used in the shop for describing the operation, although Webster properly confines "hob" to a milling cutter and "hub" to the positive master used to impress the negative form into

**Hubbing dies for molding plastics**

a coining or sinking punch.) Strange to this observer was the fact that dies for molding plastic articles, such as small radio cabinets, wear excessively at the deepest surfaces where the loose material gets the main squeeze and must move laterally to fill sidewalls. Such wear is minimized by moderately heating (plasticizing) the loose formate by ultra-high frequency currents; nevertheless they need repolishing at too frequent intervals. Such dies also are made by hubbing. The master hub, cut in a cold work die steel and hardened, is mounted in an 1800-ton press and forced into an appropriate block of low carbon steel. Surface stresses must be enormous! 0.10% carbon, 0.10% vanadium is the analysis preferred by ANDERSON for die blocks, although nickel-chromium 3110 and 0.07% carbon, 5% chromium (Carpenter's "Super Samson") have also been used quite successfully. After hubbing, the die is pack carburized for two days to produce a deep case, hardened, touched up and is ready to go.

**Metals, hazardous to health**

METALLURGISTS and men under their supervision have always been in work classed by insurance companies as hazardous, and some of these hazards have to do with poisonous materials — a matter that might seem strange to the average person who has no fear of food stored in tin, cooked in iron, copper or aluminum, eaten with nondescript flatware more-or-less adequately plated. Some of their occupational hazards are old, like lead poisoning; some of them are as new as the work on beryllium, or uranium, or the rare metals midway in weight. In the old art and practice of metallurgy the chief poison, lead, was eventually brought to heel by adequate ventilation and personal hygiene; that it is always lurking, however, was recently emphasized by an incipient case of lead poisoning in a bearing plant that is a model for cleanliness and good management. Leaching of gold ores by cyanide solutions and use of molten cyanide for case hardening are both old arts; accidents with this deadly poison are very rare, but eternal vigilance is necessary. THE EDITOR well remembers the unusual precautions (unusual for those days) thrown about a small plant for recovery of arsenic oxide from smelter fume, and his consternation on learning that a man had been killed by arsine generated in a zinc refinery where the electrolyte had supposedly been purified down to spectroscopic traces! . . . . A letter from a research scientist tells of nearly losing his life from an anemia first diagnosed as an occupational disease, and later as undue exposure to radioactivity. The accuracy of the diverse diagnoses is suspect, of course; nevertheless it is not being an alarmist to record that he was working with such conventional alloying elements as titanium, zirconium, columbium, tantalum and molybdenum. It is not being an alarmist to insist on knowing whether any of our metals, their oxides or common salts are hazardous, so we can be on our guard — and this is entirely aside from any radiation hazard. A case in point is beryllium, about which too little has been published, despite a bad record in industrial health. Human nature and ambulance-chasing lawyers being what they are, it is understandable that a firm which has had minor troubles would be close mouthed. However, when permanent disability or fatalities occur, it is time for hoisting the warning signals, even when the offending operation, substance, or any other contributory cause cannot be accurately determined. We therefore welcome a release from the U. S. Atomic Energy Commission on this subject, and recommend study of the document abstracted on page 98 of this issue. Turn also to the article on "Industrial Poisoning by Metals" on p. 755 of ⊕ Metals Handbook, 1948 edition.

**Addendum on the atom bomb**

SINCE the incredible Russians have the atomic bomb — have had it since 1947, say they, when they shouldn't have had it until 1953, said our experts — and enough such high explosive to blast a river channel through a continental divide, say they, it won't hurt any to speculate a little on what we Americans have in store and our production rate (top-drawer secrets). Supposition No. 1 — The B-36 is an atomic bomber, since it is designed to carry a 5-ton bomb 5000 miles out and come 5000 back empty. Supposition No. 2 — We have at least one bomb for each bomber. Fact No. 1 — Thirty-six B-36's were in operation in October of 1948. Fact No. 2 — Secretary SYMINGTON recently said that 75 B-36's were ordered in 1949, and 79 for 1950. Supposition No. 3 — Deliveries have been maintained at least at that rate during 1949. . . . . It looks like we have at least 125 on hand, and can now make them at the rate of at least 75 per year — that is, bombs as well as bombers.

**Another on metallurgy**

IN A RECENT copy of *Harper's Magazine*, Dr. IAN STEVENSON writes that medicine is not a science because it has too many facts and too few laws, principles. Wherein medicine is like metallurgy, says THE EDITOR. He'll bet that "⊕ Review of Metal Literature" would cite 25 how-to-do-it articles for every why-it-happened or this-is-what-will-happen.

# Elements of Metal Cleaning

# —for the Fabricator

**By Adolph Bregman**
**Consulting Editor for Metal Progress**
Consulting Engineer
New York City

*Cleaning of metal in process is so expensive, and the quality and durability of the final surface so dependent upon the cleanliness of the article, that this operation warrants careful consideration by managers and the responsible supervisors. This first article by Adolph Bregman, Metal Progress' consulting editor on metal finishing, outlines the complexity of the problem. A second article, soon to follow, will discuss some special cleaning problems and tests for the degree of cleanliness.*

METAL CLEANING is an old' art—as old as metal fabrication. As a science, however, it is young; it emerged from rule-of-thumb to controlled processes coincidentally with electroplating and metal finishing. Coincidentally, also, it has become more complex. Metal cleaning is no longer restricted to the old and simple practice of scrubbing oils, greases and waxes from the surface. The variety of foreign coatings has increased greatly and the burden placed upon cleaning has become vastly heavier. Today, "cleaning" means surface conditioning prior to welding, painting, enameling, plating or rustproofing—even the stripping of paints, enamels and various passivating films.

Because metal fabrication has also become so complex and diversified, embracing founding, machining, stamping, welding, heat treating, it is practically impossible for the fabricator to be, at the same time, an expert in metal cleaning and finishing. However, since all these operations are likely to be performed under one roof, the man in charge should understand the fundamentals of metal cleaning and its position in the manufacturing cycle. It will be the purpose of this brief article to help in this understanding by indicating some of the principal variables to be encountered. In a second article specific examples will be described more fully.

**Selecting the Proper Cleaner**—First the proper cleaning medium (and then the related matter of adaptable equipment) must be chosen. This immediately opens up a considerable realm of possibilities, for the factors influencing selection of the proper metal cleaner are:

1. THE METAL TO BE CLEANED. For example, a highly caustic, heavy-duty cleaner for very dirty iron or steel parts would be entirely unsuitable for aluminum or other relatively sensitive metals.

2. THE NATURE OF THE MATERIAL TO BE REMOVED. Soils commonly met are oils, greases, machining compounds, polishing or buffing compounds, dust, dirt, and metal chips. The oils, greases or compounds respond differently to different cleaners; a part coated with buffing or polishing compound which has been allowed to dry on the work will be harder to clean than the same part put through the cleaner immediately after polishing. A more extended list of soils is given on the next page.

3. THE DEGREE OF CLEANLINESS REQUIRED. This is generally determined by the subsequent operations to be performed on the work. A "physically" clean surface (one from which only the gross surface dirt has been removed) calls for only a simple set-up and inexpensive cleaners. A "chemically" clean surface with no water break would require a much higher degree of cleanliness.

4. THE EQUIPMENT AVAILABLE OR NECESSARY. For instance, in a power spray washing machine it would be a mistake to use a detergent containing too much soap or wetting agent. Such materials might foam right out of the machine!

## Soil Versus Cleaner

Obviously the first consideration given to the installation of a new cleaning device or the modernization of existing equipment is the type of soil or foreign matter to be removed. These include:

1. Mineral oil blanking lubricant.
2. Pure oil of a compounded type used in drilling and tapping, or on automatic screw machines.
3. Soap emulsions used in blanking or pressing.
4. Heavy soap-base drawing compounds.
5. Buffing compound constituents.
6. Graphite drawing compounds.
7. Carbonized oils, greases, or food products.
8. Asphaltic and tarry materials.
9. Corrosion products deposited on the metal.
10. Food residues, beer-stone or milk-stone.
11. Paints, varnishes, waxes.

To remove such materials the following types of cleaners are available commercially:

1. Alkaline cleaners, usually in dry, powdered form, to be mixed with water. These are of two types: *(a)* precleaners (soak) and *(b)* electro (final) cleaners.
2. Petroleum solvent cleaners ("Varsol", "Stoddard's Solvent", kerosene, gasoline).
3. Solvent emulsion cleaners, mixed petroleum spirits with emulsifiers to make them water-miscible.
4. Chlorinated hydrocarbon solvents (carbon tetrachloride, perchlorethylene, trichlorethylene).
5. Acid cleaners.
6. Molten salts.

Cleaning chemicals generally should be stored away from steam pipes or other sources of heat which may cause reactions under which they may deteriorate, or even explode. Compounds containing petroleum solvents constitute fire and explosion hazards. Chlorinated hydrocarbon solvents are toxic; thus, contact and fumes should be avoided.

Obviously it would take many closely written pages to discuss all the above variables, which apparently would lead to an infinite number of combinations. Before describing the unit *operations*, however, a few short paragraphs may well be devoted to the first category of cleaners mentioned above.

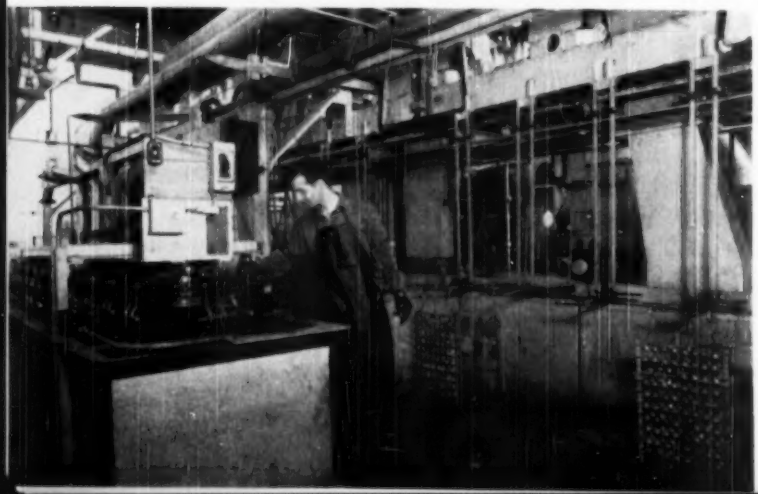
Alkaline detergents are required to meet a wide variety of demands. Consequently, they are of varied types such as "heavy-duty" and "light-duty" cleaners for steel; etching and nonetching cleaners for aluminum and brass; cleaners containing natural or synthetic wetting agents for use as a spray or in soaking tanks; electrocleaners for anodic or cathodic cleaning; cleaners for plant maintenance, and so on. Such detergents must be long-lasting, must rinse readily and must operate easily.

The complexity of present-day metal cleaning may be judged from the variety of materials now used in the alkaline cleaning operations, alone and in combination. We enumerate soda ash, trisodium phosphate, tetrasodium pyrophosphate, caustic soda, sodium metasilicate, sodium sesquisilicate, sodium orthosilicate, rosin, sodium resinate, solublized solvent (protective or nonprotective type, with or without kerosene), and finally a variety of wetting agents.

Constituents used in small proportions are such solvents as orthodichlorbenzene, butyl cellosolve, pine oil or petroleum distillates, and such materials as bentonite, colloidal clay or volcanic ash.

The most commonly used alkalis are soda ash, caustic soda and trisodium phosphate. Tetrasodium pyrophosphate is employed sometimes as a substitute in part for trisodium phosphate or sodium metasilicate where hard water must be used.

*Fig. 1 — Fully Automatic Conveyer Shown at Right Is Used for Cleaning Only. In this plant several different types of plating are required after the cleaning, so the latter is done on a fully automatic conveyer; the clean work is transferred to a semi-automatic conveyer (left) for plating, and then returned to the first conveyer for final rinsing and drying. This is one of the most modern and best systems where several finishes are required. (Courtesy Hanson-VanWinkle-Munning Co.)*



## Methods of Cleaning*

Several main general types of cleaning methods will now be briefly discussed.

**Soak Tanks** — Cleaning in soak or still tanks requires the use of higher concentrations of cleaning materials — up to 10 oz. per gal. The temperature of the solution should be as high as practicable, generally from 180 to 212° F.; this aids in agitating the bath and provides maximum speed and effectiveness of operation. Cleaning time is usually from 2 to 12

*Acknowledgment is made to General Motors Standards from which data were adapted for this section.

min. It is often possible, however, to reduce the total cleaning time substantially by dividing the cleaning cycle into two parts. The major portion of the soil may be saponified or emulsified in the first cleaner tank, then removed by an intermediate spray rinse, and the less concentrated residue easily removed in a final cleaner tank.

**Power Washers** — Power or spray washers provide an economical method for removing light soil. They do not give the high degree of cleanliness required for fine finishing operations, but they are adequate for low-cost intermediate operations. Their scouring action makes it possible to use low concentrations, from ⅛ oz. to 1 oz. per gal. of the cleaner. Such cleaners are usually of the straight alkali type containing soaps or resinates, but various emulsion cleaners may also be used, provided the concentrations and temperatures are controlled to avoid excessive foaming. The temperatures are usually between 170 and 200° F. for alkaline cleaners, and 140 to 160° F. for emulsion cleaners. Spray nozzles must be kept clean and clear. Equipment is preferably completely enclosed, to control mist, splash and steam.

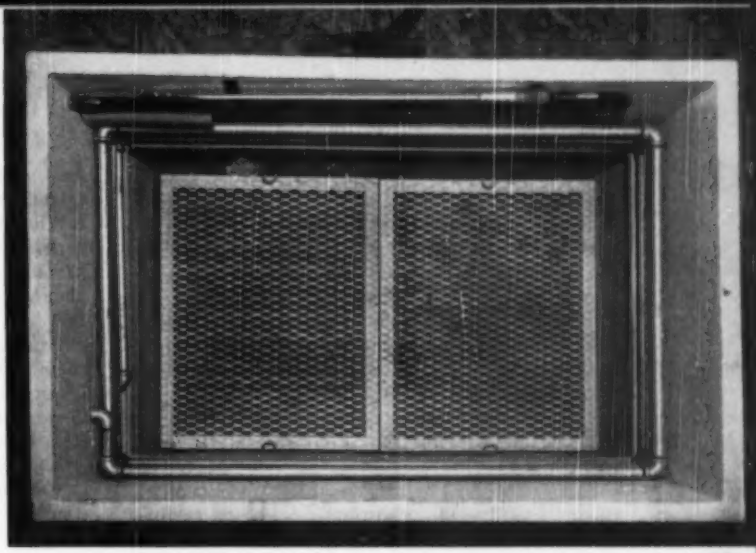


*Fig. 2 — Looking Down Into Vapor-Spray Degreaser. Work rests are at bottom and cooling coils around sides. Operator works from side on which spray hose is located, at top of illustration. (Courtesy Optimus Equipment Co.)*

**Electrolytic Cleaning** — There are three types of electrolytic cleaning: cathodic, anodic, and a combination of the two.

Cathodic cleaning is more effective because much more gas is released at the cathode (the work) than at the anode, and this loosens the soil — but at the same time metals, and even some nonmetals, are deposited on the work. In anodic cleaning, on the other hand, the ions travel away from the work and there is consequently no danger of deposition. However, there is the possibility the cleaner may attack the work by chemical action. In electrolytic cleaning it is usual to employ 3 to 9 volts, and a current density of 25 to 100 amperes per sq.ft. The solution concentrations range from 3 to 10 oz. per gal. The temperature range is from 160 to 212° F.

Combination cathodic and anodic cleaning calls for preliminary cleaning with the work as the cathode; in the final phase the current is reversed and the work becomes the anode. Materials that have been deposited during cathodic cleaning can then be removed. It has also been stated that the current reversal still further loosens the soil from the surface of the work and facilitates rinsing.

**Emulsion Cleaning** — Emulsion cleaners consist of petroleum compounds such as "Varsol", "Stoddard's Solvent", kerosene, gasoline or hydrogenated naphtha mixed with soaps, emulsifiers and wetting agents to form "solublized" cleaners. They are very effective in dispersing caked-on insoluble materials, heavy oil, grease, drawing compounds and slushing compounds. They also leave a thin rust-inhibiting film on steel parts.

The mixture can be used as a soak cleaner in a tank; it can also be brushed or sprayed on the parts to be cleaned. It can be rinsed with either water or a petroleum solvent. Using water, the first rinse consists of a cold water spray, followed by hot water or a blast of clean dry air. The hot water rinse, if by immersion, should be operated above 180° F. and should overflow constantly to clear it of floating scum. Agitation and hand brushing will speed and improve the cleaning operation. Rinsing can also be done in a mechanical washer in which a small amount of the solvent cleaner (1 part in 500) should be added to the rinse water. If straight solvent is used as a rinse, a small amount (about 10%) of the cleaner base should be added to the solvent for improved rinsing and protection against rust.

**Solvent Degreasing** — Other and stronger solvents are hydrocarbons containing chlorine, such as carbon tetrachloride or trichlorethylene. They may be used as vapor, liquid (by spray), liquid (by immersion), or a vapor-spray-vapor combination. Vapor leaves work cleanest and is generally the final step in the precleaning. Immersion in boiling solvent aids physically in dislodging heavy soil, the pressure spray is more effective, but the vapor-spray-vapor combination is the most effective precleaning cycle. However, none of these

chlorinated hydrocarbons are very effective against the inert, insoluble soils, such as abrasives in metal finishing compounds, soaps, oxidized lanolin, or sooty carbon in lubricants. Their action is simply the dispersal of the inert materials so that they may be rinsed off.

**Acid Cleaning** — Acid cleaners can remove oxide films from metals when pickling is impractical — such as, for example, cleaning aluminum prior to spot welding.

Light rust deposits on finished parts can be removed by the use of phosphoric acid rust removing solvents containing alcohols or esters, suitably diluted (3 to 10 parts water), followed by rinsing and drying. Phosphoric acid rust removers are especially recommended for work which is to be lacquered or enameled. Parts which have been stripped of paint, enamel and lacquer should be immersed in a dilute solution of this type in order to neutralize the residual alkali, passivate the surfaces and protect against rusting.

Steel parts with heavy deposits of rust or scale are commonly pickled in 8 to 10% sulphuric acid solutions at 140 to 160° F., after alkaline cleaning and rinsing. (Obviously, a better scheme is to prevent such excessive rusting.) Lighter rust can be removed by shorter dips in 50 to 100% commercial hydrochloric acid. In either bath an inhibitor is used to limit the attack on the base metal. The pickle is followed by a water rinse and a neutralizer dip, such as soda ash or a mild alkaline cleaner.

Inhibitors in pickling baths are also used to limit the attack on tin plate, and hot-dip and electrogalvanized steel. For this application, good practice is to use 0.5 to 0.6 oz. of inhibitor per gallon of pickling solution (ordinarily a 50% solution of commercial muriatic acid).

**Rinsing** — It must be borne in mind that the quality of the finished or plated work is dependent upon the thoroughness of rinsing. The rinse water should be maintained as clear as possible by continuously overflowing. Fresh water may be introduced at one end of the tank through a pipe leading down near the bottom of the tank; a weir or box overflow is located at the other end. Temperatures range from 180 to 212° F. Heating coils should be some distance from the overflow to give the best agitation without interfering with the skimming action. If steam jets are employed, they should be directed toward the entrance end. Cleaner tanks in intermittent use may also overflow at intervals, for skimming, by valves on drain lines located near the surface.

Power washers require a clear water rinse; consequently, the rinse tank should continuously overflow a weir. In hard water districts, softened water or steam condensate should be provided for the rinsing, the temperature held below 135° F. to prevent breakdown of the calcium and magnesium salts which will leave deposits on the work. A calcium carbonate film, for example, will prevent the proper flow of the copper in copper brazing.

## Role of Management

It should be clear from the foregoing that metal cleaning has become a complex specialty. The responsible operator of metal shop or plant should know its broad applications, its capabilities and limitations and the operating principles of the equipment used. However, he is rarely an expert on metal cleaning as a specialty. In many organizations the metallurgist has responsibility for such matters. Whoever he is or whatever title he may bear, he will be well advised to listen to the expert advice of his supplier. A manufacturer of cleaners who is properly staffed will be able to solve many operating problems if given all pertinent data.

One large manufacturing organization with complete and detailed specifications has recognized this fact by establishing the policy that, instead of specifying definite chemicals for use as wetting agents or emulsifiers, a certain amount of responsibility is placed on the vendor of cleaners toward giving the newest and best cleaner for the job, and the proper percentages needed. This provides a source of assistance to the buyer of cleaners, since the supplier can be called in if any trouble arises in the cleaning setup.

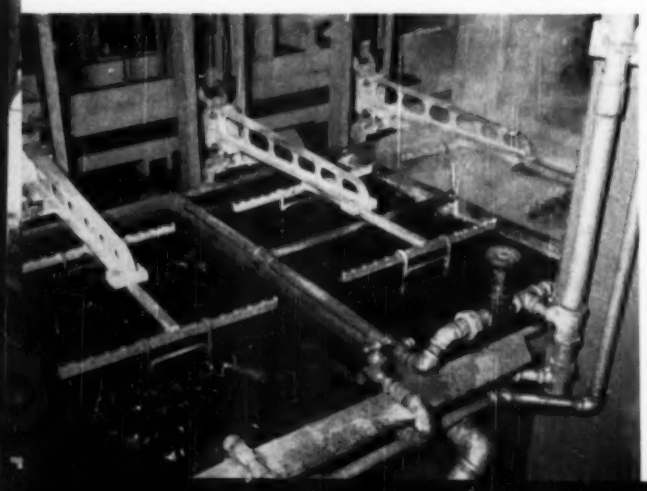


*Fig. 3 — View Over the Rinse Tanks and Dryer on a Hanson-VanWinkle-Munning Heavy-Duty, Fully Automatic Electroplating Conveyer. Note the rapidly agitated cold-water rinse, followed by the same with auxiliary spray heads, a hot-water rinse, and then the dryer tunnel at far right. A cycle consisting of at least two cold-water and one hot-water rinses before drying minimizes stain.*

# Correspondence

## Producing As-Cast Ferritic Nodular Iron in Heavy Sections

GHENT, BELGIUM

This letter concerns the production of ferritic nodular iron in sections of various sizes. In the tests referred to here, we poured solid cylindrical castings of diameters 30, 80, 150, 250 and 350 mm., and a hollow cylinder of 150 mm. wall thickness, from a ladle containing 4 tons of iron. This iron came from the cupola with a composition of 3.60% carbon, 1.4% silicon, 0.30% manganese, 0.05 to 0.07% sulphur, and 0.07% phosphorus. This metal was then treated, in one operation, with an alloy containing 60% silicon, 20% magnesium, 10% nickel and 10% iron. With a special addition method (patents pending) and for the above-

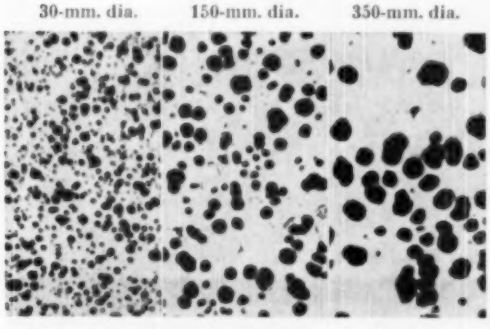



*Fig. 1 to 3 — Graphite Distribution in the Centers of Cylinders Having the Diameters Indicated. 25×*

mentioned iron (0.05 to 0.07% sulphur), 2% of the addition alloy is more than sufficient and gives a residual magnesium content of 0.06 to 0.10%. The addition method is perfectly safe and gives constant results.

The sections 80 mm. diameter and larger were not only fully nodular but also more than 90% ferritic. With increasing diameter of section, the diameters of the graphite spherulites increase as follows: 30-mm. section, 50μ graphite spherulites; 80 mm., 55μ; 150 mm., 90μ; 250 mm., 120μ; 350 mm., 130μ. Figures 1 to 3 show the distribution of graphite in the centers of cylinders 30, 150 and 350 mm. in diameter. In the heavy section there is a marked tendency for the graphite spherulites to be concentrated in groups, as shown in Fig. 3.

Another important feature, at least in a hypereutectic composition (in the iron discussed here, 3% silicon after treatment with the silicon-magnesium alloy and secondary inoculation with 0.6% silicon iron), is the graphite segregation in a thin layer at the top of heavy castings. This is

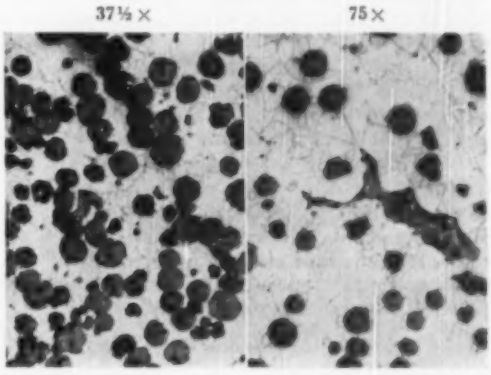



*Fig. 4 and 5 — Graphite Segregation in Top Layer of a Hypereutectic Heavy Casting (Left) and Sample From Body of a Heavy Casting of Ferritic Nodular Iron (Right)*

shown in Fig. 4, representing a sample taken 10 mm. below the top surface of a hollow cylinder 150 mm. thick. A test bar machined from the body of this casting (structure shown in Fig. 5) gave nearly the same results as those obtained from test bars machined from the centers of 150- and 250-mm. diameters. Tensile properties from A.S.T.M. "Specimen A" test bars are as follows:

| Position in Casting | Tensile Strength | Elongation | Brinell Hardness |
|---|---|---|---|
| Center of 150-mm. cylinder | 70,700 psi. | 8.4% | 187 |
| Center of 250-mm. cylinder | 70,000 | 6.0 | 184 |
| Body of 150-mm. section | 72,500 | 5.5 | 180 |

ALBERT DE SY
Professor of Metallurgy
University of Ghent

## Improved Techniques for Examination of Structure

CHAMPAIGN, ILL.

It has been our experience, repeated many times, that the foreman, inspector and production manager have difficulty in evaluating photographs taken with the metallurgist's camera, for instance, in correlating a 4 x 6-in. micrograph with a tiny spot on a metal section and appraising the evidence.

We believe there is great advantage in being able to section a part, forging or casting, or a part returned from service, study the *entire* picture of the section and then enlarge any portion desired for more detailed examination.

Such a scheme has been used on small parts by H. H. Harris of General Alloys Co. in Boston, and has now been perfected so it can be applied to large castings. This work has been a byproduct of a U. S. Navy Research and Development contract at Alloy Engineering & Casting Co. of Champaign, Ill., with the aid of technicians from the casting and forging section of the Bureau of Ships and the materials section of the Bureau of Aeronautics.

The equipment includes a specially adapted hydraulic saw which will rapidly cut 20x20-in. castings — including cobalt alloys and other high alloys — and a Bullard vertical lathe with which we can surface-machine castings after cutting. Final finishing will be done on a 30-in. Blanchard grinder. Our technique is as follows:

1. Section the entire casting on the hydraulic saw.
2. Machine on Bullard lathe to a fine finish.
3. Grind to a superfinish on Blanchard grinder.
4. Etch the entire section in the special reagent, developed by N. J. Grant at Massachusetts Institute of Technology, to reveal as-cast grain structure.
5. Swab specimen with ether, then lens coating.
6. Take two photographs of same with largest magnification possible on a spring-mounted 40x40 enlarger camera such as used by photo-engravers.

   *(a)* Use slow film of very fine grain size.
   *(b)* Stop down lens for extremely fine definition at long exposure.
   *(c)* Develop film to minimize graininess.
   *(d)* Make identical films by above routine, one to be preserved for making full-size prints, the second to be covered with a loose transparent leaf ruled off in cross-indexed 35-mm. strips.
   *(e)* Any portion of the second film may be selected by index reference from the indexed transparency and blown up on a precision 35-mm. enlarger to any desired magnification. Enlargements are sharp and effective to 200 ×.

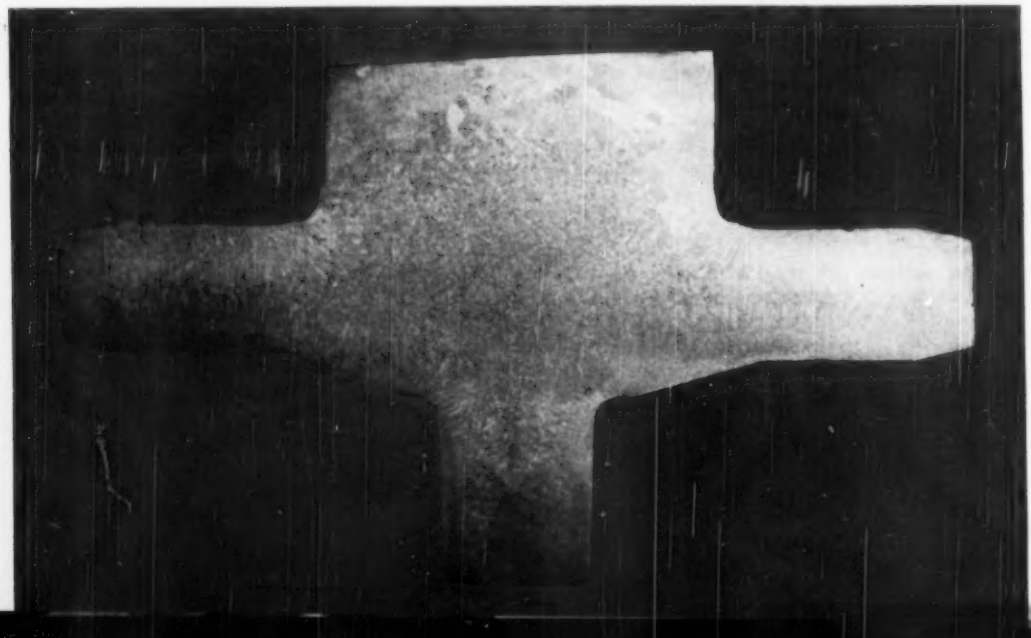
In this manner we record the structure of a part with a full-size macrograph and provide for "photomicrographs" of any part of the section, accurately located for comparison.

Such a procedure will provide for the first time a thorough-going check on the grain size and casting techniques of commercial castings, and will clearly reveal on a large-scale wall exhibit what has heretofore been inadequately represented by hundreds of individual photomicrographs hung together like a World War I aerial photo-mosaic.

Certain advantages are inherent in the equipment above listed, such as the accurate polishing of the Blanchard, the fine resolution of the engraver's lens, and the fidelity of slow film.

ARTHUR L. LAMASTERS
Vice-President
Alloy Engineering & Casting Co.

*Section Through 320-Lb. Centrifugally-Cast Wheel Made of N-155 Alloy*



Shells of these tanks are 3/16" thick and are made of 20% chromium-nickel stainless-clad over mild steel. Likewise, manhole necks and covers have 20% stainless clad interiors. Necks of vents are ¼" solid stainless steel, with mild steel flanges.

# HOW STAINLESS-CLAD *and* SOLID STAINLESS STEELS *Provide Vital Advantages for Beverage Storage*

This interior view of a hoisted tank shows the solid stainless steel angles used for top bracing.

Complex needs of the beverage processing industries have led to the use of several different chromium-nickel stainless steels to solve specific corrosion problems...

But corrosion resistance is only one of the many virtues of austenitic chromium-nickel stainless steels.

In addition, they are readily fabricated, may be welded with ease and are highly resistant to impact and wear. Parts made of these stainless steels are easy to clean and keep clean.

Charles T. Brandt, Inc., of Baltimore, Md., constructed the two 25,000-gallon storage tanks shown here of Type 304 stainless-clad and solid stainless. The tanks are adequately strong, are corrosion resistant, and do not contaminate the stored syrup.

Leading steel companies produce chromium-nickel stainless steels in all forms such as sheet, strip, bars and tubes. A list of sources of supply will be furnished on request.

Choice of the correct type for your application assures longer service life, fewer repairs and minimum maintenance.

Over the years, International Nickel has accumulated a fund of useful information on the properties, treatment, fabrication and performance of engineering alloy steels, stainless steels, cast irons, brasses, bronzes, nickel silver, cupro-nickel and other alloys containing nickel. This information is yours for the asking. Write for "List A" of available publications.

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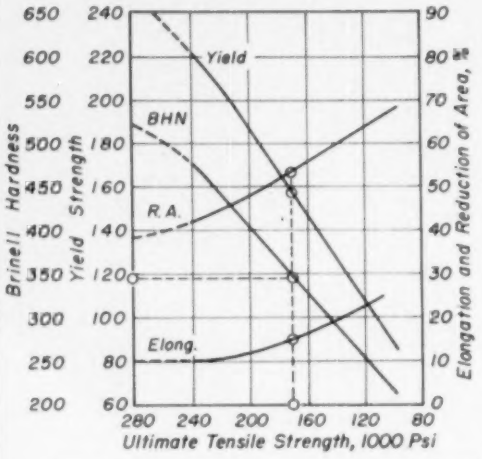
**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET NEW YORK 5, N.Y.

# Properties of Through Hardened Steels

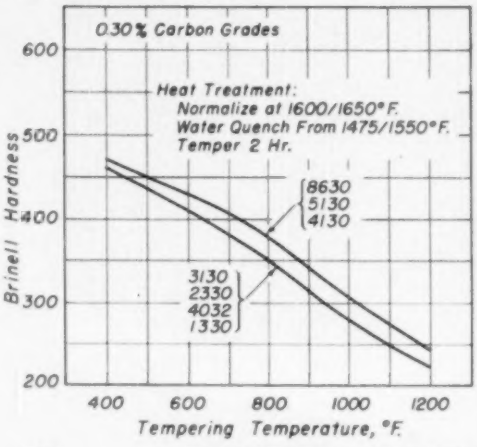
*From "Republic Alloy Steels", 1949 Edition*

THESE CHARTS apply only to steels in small enough section so they quench out to at least 90% martensite. Under such circumstances the approximate relationship between hardness and tensile properties is as shown in top left diagram, irrespective of chemical composition.

Suppose the design requires an average tensile strength of 170,000 psi. Erect a vertical as shown; its intersection with the various curves shows that the Brinell hardness will be about 345, the yield strength about 157,500 psi., the elongation about 15% and the reduction of area about 52%.

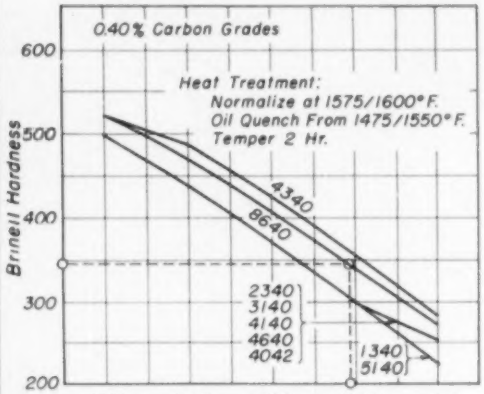



Assume further the stock available is A.I.S.I. standard 8640. The dotted lines on the lower left diagram show that the part should be tempered (after indicated normalize and quench) at about 980° F. Maximum size of such a part is shown to be 1.4 in. in the table under the lower diagram.



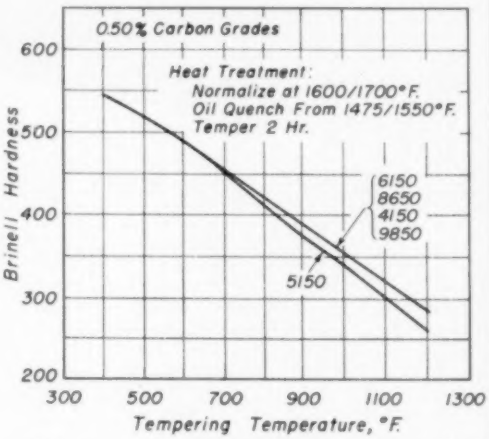

| Grade | Maximum Hardness | | Max. Size* |
|---|---|---|---|
| 1330 | 174 annealed | 241 normalized | 1.5 in. |
| 2330 | 183 | 241 | 1.4 |
| 3130 | 174 | 241 | 1.2 |
| 4032 | 174 | 228 | 1.0 |
| 4130 | 174 | 255 | 1.4 |
| 5130 | 170 | 241 | 1.25 |
| 8630 | 179 | 255 | 1.5 |

Forgings (at 2250° F. max., except 2200° F. for 2330) should be annealed at 1500 to 1700° F. and furnace cooled.




| Grade | Maximum Hardness | | Max. Size* |
|---|---|---|---|
| 1340 | 183 annealed | 269 normalized | 1.25 in. |
| 2340 | 202 | 269 | 1.0 |
| 3140 | 187 | 302 | 1.4 |
| 4042 | 182 | 235 | 0.6 |
| 4140 | 197 | 300 | 2.0 |
| 4340 | 223 | 415 | 4.0 |
| 4640 | 197 | 285 | 1.1 |
| 5140 | 187 | 269 | 1.0 |
| 8640 | 197 | 302 | 1.4 |

Forgings (at 2250° F. max., except 2200° F. for 2340) should be annealed at 1500 to 1700° F. and furnace cooled.




| Grade | Maximum Hardness | | Max. Size* |
|---|---|---|---|
| 4150 | 212 annealed | 375 normalized | 3.1 in. |
| 5150 | 202 | 293 | 1.2 |
| 6150 | 202 | 302 | 1.6 |
| 8650 | 212 | 355 | 2.0 |
| 9850 | 223 | 387 | 3.5 |

Forgings (at 2250° F. max.) should be annealed at 1475 to 1725° F. and furnace cooled.

*The maximum cross section in which the tempering response noted in the diagrams can be expected, when treated as recommended.

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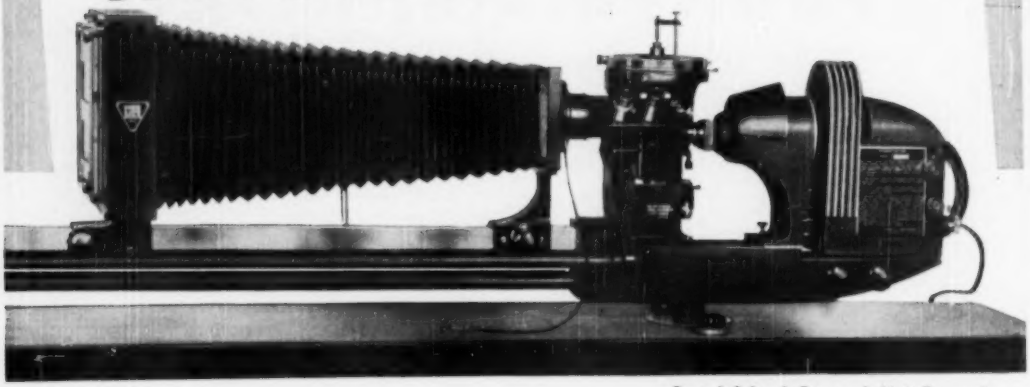
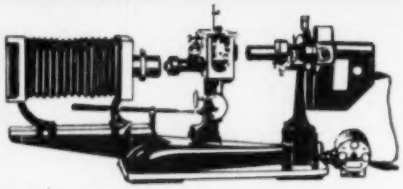


Bausch & Lomb Research Metallograph



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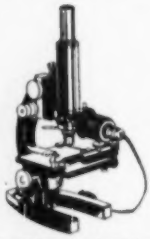

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# Use of Boron Steel in Production

**By Fred J. Robbins**
Vice-President
**and J. J. Lawless**
Assistant Metallurgist
Plomb Tool Co., Los Angeles

DURING the last several years and particularly during the recent war, metallurgists have become increasingly anxious to have steel specifications better fitted to the field service requirements for the part to be made. There are several reasons for this interest, but probably the most important is economy. It is costly to overgrade. While such practice has been extremely common in many industries, and still probably is, many managers and metallurgists are insisting on the use of steels providing exactly (or as nearly so as possible) those requirements actually necessary. It would be desirable therefore to have available enough grades of steel to completely cover the range of hardenabilities in order to eliminate any necessity for overgrading.

Much research effort has been devoted to the various alloying elements that could be used to provide the necessary predetermined characteristics upon suitable heat treatment. One element that has received considerable attention is boron. Information about boron is not yet widespread among the metallurgical profession, although numerous data have been obtained, and some are already published. From 1943 to 1946 the War Engineering Board of the Society of Automotive Engineers sponsored a project in which 130 tons of boron steel was processed in small quantities by a number of manufacturers. The results were reported in some detail by the Ordnance Department's Research and Development Board in August of 1946 in publication R.A.D. 1448. A paper reporting the method and effects of boron additions to various analyses of steel also was printed June 1945 by the Bureau of Mines as Report of Investigations No. 3816 entitled "Effects of Boron in Steel" by R. B. Corbett and A. J. Williams. Robert S. Archer has summarized the situation in *Metal Progress* for October 1946, p. 677.

However, so far as is known to the present authors, no detailed report of tests and uses of this material, based on large tonnages, has thus far been published. We have been responsible for the development of a specification for boron steel based upon hardenability (determined by the standard Jominy test) and have supervised the consumption and production-use of large quantities of this type of material. Consequently we feel that we are qualified to discuss the characteristics of a boron steel, made to this specification, and to evaluate it with respect to other analyses commonly used for similar products.

It is the purpose of this paper, therefore, to discuss one particular boron steel which was developed in the light of wide experience with service of parts. It will attempt to evaluate the material on the basis of various production operations such as forging, hot forming, machining on automatic screw machines, and standard heat treatment, that are encountered in mass production. Data will be presented, based upon standard hardenability, tensile, and impact tests, so that the reader may be able to reach some conclusion with respect to the applicability of this type of material to his own requirements.

The parts under discussion previously had been made from such material as A.I.S.I. 4142 chromium-molybdenum steel, and more recently during the war, of N.E. 9440 (chromium-nickel-molybdenum). Accordingly, in setting up a specification to cover the boron steel it was felt that a material was required which would approach one or both of these analyses in its general characteristics. Because the sections are relatively small, a deep hardening steel is not required, and after some experimental work a minimum specification of Rockwell C-45 hardness at $\frac{5}{16}$ in. on the Jominy bar was decided upon as the governing requirement. By means of Grossmann's hardenability factors* it was found that this specification should be met with reasonable expectancy by a steel with 0.45% carbon and 0.90% manganese, using stand-

*See Metal Progress Data Sheet No. 51.

ard alloy openhearth practice, deoxidized with enough silicon for 0.22% residual — providing all conditions are optimum with respect to analysis and the production processes. This steel corresponds to the standard C1045.

As was already known, however, such a medium manganese steel without any other alloy additions will be erratic in its response to heat treatment. A representative Jominy curve made on this type of material is shown at lower left of Fig. 1. It was immediately recognized, therefore, that in order to provide the response required for production heat treating operations, and to insure uniform mechanical properties along with reliable field service results, the addition of some alloying element would be required, and attention was devoted to boron.

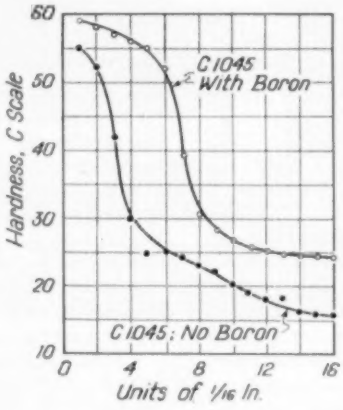



*Fig. 1 — Jominy End-Quench Curves for Medium Manganese Steel C1045 With and Without Boron Additions. Prior heat treatment: Normalize at 1650° F., quench from 1550° F. Basic analysis: 0.43% C, 0.85% Mn, 0.26% Si, 0.06% Cr, 0.01% Mo, no Ni, 0.04% max. S and 0.04% max. P*

It is apparent from an examination of the curve at the right in Fig. 1 that the boron provides the expected additional hardenability over the basic analysis. If the same hardenability were to be obtained in a straight carbon steel, both carbon and manganese would have to be maintained at the indicated level or higher. Even if they were, attendant disadvantages in production would occur. However, higher average carbon and manganese would defeat the purpose because both tend to make for difficult machining, poor tool life, and poor finish. Furthermore, *close* control over both carbon and manganese is not practicable in steel production, and the ductility-strength ratios of higher carbon steels at a given surface hardness are lower than when the same hardness is obtained with lower carbon and manganese.

From these considerations it is apparent that the addition of boron makes a steel with properties that bridge the gap between the so-called medium-carbon machine steels and the standard lean alloy steels such as chromium-molybdenum and chromium-nickel. This fact is further illustrated in Fig. 2 in which hardenabilities for various 0.40-carbon steels and a typical boron steel are shown.

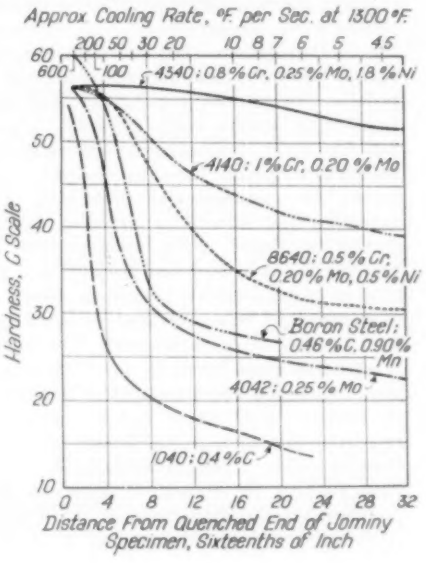
The basic concepts of hardenability, established by various investigations, show that for all practical purposes the physical properties concerned with strength in steel are directly proportional to the average hardness of the section, and the alloy content is of importance primarily in influencing the reaction to hardening and tempering operations. We will proceed on this basis, ignoring fatigue and impact resistance, and assume that any material capable of achieving adequate hardness throughout the section will have suitable mechanical properties for ordinary uses.

In Fig. 2 we show hardenability curves for typical heats of various 0.40% carbon steels and a boron steel of analysis specified in the caption of Fig. 1. If we assume that a product calls for specific physicals equal to Rockwell hardness C-40, then the materials cited in Fig. 2 may be applied where the slowest cooling rates are as follows (under pertaining conditions of section size, shape, and efficiency of the quenching system):

| | |
|---|---|
| C1040 | 150° F. per sec. |
| A4042 | 60° |
| Boron steel | 40° |
| A8640 | 17° |
| A4140 | 5° |

It is apparent that the boron steel has a relatively low critical cooling rate as compared to C1040,

*Fig. 2 — Boron Steel Gives Hardenability Curves Intermediate Between Plain Carbon Steel and Lean Alloy Steel. All samples have approximately 0.40% carbon. Curves (except for boron steel) from Climax Molybdenum Co.'s "Molybdenum Steels, Irons and Alloys"*



and a somewhat higher critical cooling rate than A8640 and A4140.

In the specification of a material such as is under discussion, where experience is limited both on the part of the steel manufacturer and the consumer, considerable interest in the *uniformity* of the product would be natural. Specification under which this material is purchased requires a minimum hardenability of J45 at 5 (Jominy hardenability test showing at least C-45 at 5/16 in. from the quenched end).

At the beginning of this project a heat was made occasionally with hardenability below that specified. When such a substandard heat did occur it was of interest to observe the response of the material in production. As would be expected it was found that results would be short of requirements for any given section, production cycle, and hardness after heat treatment, unless the material was applied where lower hardness could be specified. (In some instances, the heat was diverted to other applications entirely.) Failure to meet the specified hardenability was always detected through routine hardenability tests at the time the heat was made and before it was rolled, so the entire heat could be rolled into small sizes where experience showed that lower hardenability would not prove troublesome to the user.

In working with a hardenability specification wherein the steel type is intended to have only the minimum alloy necessary to provide such hardenability, careful control is quite necessary because heat treatment of material low in hardenability is always expensive and difficult in mass production. As the steel suppliers became experienced, substandard heats became fewer and fewer, and now occur very rarely, indicating that enough

***Experience with the conversion of several thousand tons of boron steel (0.45% carbon) into forged, machined and heat treated parts for heavy duty has convinced Messrs. Robbins and Laudess that the material is unusually insensitive to normal heat treating variables, that annealing in continuous furnaces produces structure satisfactory for screw machine operations, that machinability (parts per tool grind) is superior, and that service failures are no higher than with the triple-alloy or the conventional low-alloy standard steels. (This paper was read at the 1949 Western Metal Congress.)***

experience with boron can be gained to prevent difficulty in meeting specified requirements. Out of 70 heats supplied by one source it was found that C-45 occurred between 4 and 5/16 in 10 heats, between 5 and 6/16 in 36 heats, between 6 and 7/16 in 16 heats, and over 7/16 in 8 heats. Of those heats showing hardenability greater than specified (J45 at 6), 75% contained residual chromium and nickel of the order of 0.20 to 0.30%, as did all of those showing better than J45 at 7/16. Also, all but four of the higher hardenability heats were made in the first 36 heats produced. The subsequent 34 heats showed much better uniformity with hardenability; J45 at 6/16 was exceeded in only four heats and less than J45 at 5/16 occurring in only six heats.

Reliability is dependent upon the uniformity of the material, not only from heat to heat but also from ingot to ingot within the heat itself. In order to determine the uniformity *within* the heat, hardenability tests were required for steel in the first, middle, and last ingots of each heat. Further, to test the uniformity within the *ingot*, in the earlier heats samples were taken at the top, middle, and bottom of these three ingots.

Figure 3 shows the results of Jominy tests performed in accordance with this procedure, and illustrates the uniformity of hardenability found in one typical heat. After a sufficient number of heats — about 50 — had

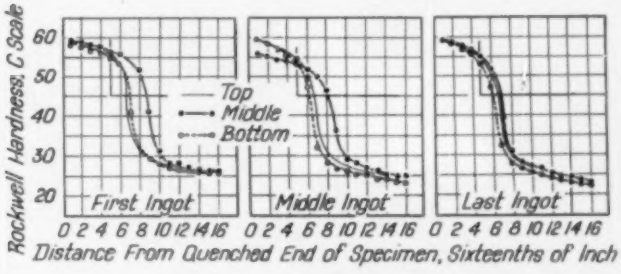



*Fig. 3 — Jominy Tests Made From Top, Middle and Bottom of First, Middle and Last Ingot of a Typical Heat of Boron Steel Show Uniformity of Material. Specification: Hardenability greater than C-45 at 5/16 in. Analysis: 0.43% C, 0.85% Mn, 0.26% Si, 0.06% Cr, no Ni, 0.01% Mo*

been tested under this procedure, it established the reliability of the material, and subsequently only one test was taken from each of the first, middle, and last ingots.

It is believed that these data satisfactorily establish that boron steels may be expected to be both reliable and uniform enough to attain commercial results.

## Forging Characteristics

In considering the performance of any steel in production, one extremely important fabricating operation to be scrutinized is forging. Large tonnages of the material described have been forged in closed impression dies on board-drop hammers where die life is an extremely critical consideration and seriously influences the cost. Some data have been gathered in past years which show that the presence of various alloys in the steel being forged reduces considerably the number of finished forgings that can be obtained from a single die. Further, it seems true that if the amount of these alloying elements or their number is increased, die life becomes poorer and poorer.

Generally, the straight carbon steels give a fairly good die life. In the forging of one specific part where N.E. 9445 steel was used a life of 13,000 to 15,000 pieces per die sinking was obtained. With precisely the same requirements in the finished part from the standpoint of mechanical properties, dimensions and other characteristics, between 22,000 and 25,000 forgings per die sinking resulted with boron steel. Naturally, this meant a considerable reduction in the cost of this operation. By conservative estimate based upon experience with some 10,000 tons of boron steel, forged at 2150 to 2250° F., about 25% greater die life was achieved than obtained with the so-called lean alloys of the same carbon content.

*The Drop Forge — Photo by Wm. T. Lyon*

Decarburization resulting from the heating for forging, and influenced considerably by the previous rolling operations, is of interest to the metallurgist in respect to subsequent operations and the development of final specified hardness after heat treatment. Our studies have failed to indicate any greater tendencies toward decarburization of the boron steel — either when compared to straight carbon steels of comparable carbon content, or to the alloy steels for which the boron steel can be substituted. Decarburization in forging (as it applies to the grades under consideration) appears to depend much more upon the physical conditions of heating for forging, such as temperature range, temperature control, heating cycle, and furnace equipment rather than upon steels' analyses. (The furnaces used for the operations described are the open-slot type, oil-fired, commonly used over the country.)

On the other hand, scale is a considerable factor in die life, and scaling characteristics are related to the analysis of the material. The boron steels were found to possess a much lighter, less adherent scale in the finished forging than the higher alloy types. Scale formed on the boron steel more nearly corresponds to that on straight carbon steel. Being loose and flaky, it can be easily removed in the forging die itself with little tendency to be driven into the surface of the forging. The scale formed on an alloy steel is a tightly adhering scale, which (while thin) is very often more difficult to remove than the thicker but looser type of scale.

A considerable advantage is found in subsequent cleaning operations. Using a standard No. 40 steel grit, mechanically thrown on the parts, it was found that a 15-min. cycle cleaned up the boron steel forging. Those alloys which needed a more prolonged heating cycle in annealing and formed a tight, adherent scale generally require about 30% longer cleaning cycles for similar results. Forgings of A4340, for example, have required 25 to 30 min. for cleaning.

Experience with a large tonnage indicates that the boron steel does not exhibit any unusual characteristic detrimental to the production of good forgings under standard practice.

## Heat Treatment for Machinability

Where machining operations such as broaching, milling, or drilling are performed on forged parts, those microstructural conditions which control speed of cut, feeds and finish are of extreme importance, and represent a large portion of the final cost. Considerable savings are possible where annealing operations can be performed on a continuous basis and still provide suitable microstructure and hardness for producing parts with acceptable finishes, good tool life, and a minimum of trouble. One factor which makes for trouble in machining and which has been largely overlooked is *uniformity*. Continuous annealing operations, properly devised, adequately controlled, and intelligently supervised, keep costs low in the machine shop, and assure maximum, uniform production rates with a minimum of machine downtime and other interruptions in production. The use of continuous furnaces for such operations has proved to be far more productive of suitable results. Experience has shown that the boron steels are peculiarly adapted to a normalizing treatment at 1650° F., followed by a tempering operation at a temperature to provide hardness in the part determined by experimentation to be best suited for a given machining operation. Mass production in this way requires a minimum of labor and the lowest possible cost in the heat treat. Furthermore, the operating cycle is only about one third of that required for the higher alloy types.

For such an operation to be a part of the over-all production cycle, a steel of suitable hardenability must be used. The boron steel of the analysis under consideration is adapted to this requirement, since about C-30 hardness is maximum in even the smaller sections after normal air cooling from the normalizing temperature. An acceptable uniformity is found except where extreme variation in section size exists, or where the cooling rates may be affected by physical contact with other forgings; this, of course, can be controlled by mechanical means. By contrast, other alloys, such as A 4140 and N.E. 9445, usually develop hardnesses as high as C-50 in the lighter sections. Owing to their slower transformation rates, it is much more difficult to reduce this hardness by short tempering treatments. In view of the high hardness developed in these alloys, it is completely impossible to trim the flash from forgings prior to annealing, whereas with boron steel and its relatively low hardness after air cooling, the forgings can be trimmed immediately with a satisfactory die life.

From the standpoint of economy, the adaptability of the boron steels to low-temperature annealing programs is probably their most outstanding advantage. In one of the plants we are acquainted with, two continuous furnaces arranged for normalizing, partial cooling, and high draw have replaced six box furnaces. The continuous equipment operates for 8 hr., consuming approximately 20,000 cu.ft. of gas, and requires only one operator. In order to handle equivalent production,

the superseded equipment was operated for 16 hr., consuming approximately 15,000 cu.ft. of gas, and required six operators. Actual operation over a 2-year period has established that the boron steel is also much more uniform in hardness and structure. Continuous annealing cycles can be readily designed for any steel, but the slower transformation rates of the higher alloy steels impose longer annealing cycles, and larger and more expensive equipment is required.

The objective of annealing has been a structure and hardness generally suitable for a variety of machining operations, such as shearing or trimming, milling, broaching, drilling, tapping, secondary turning. Here we see the need for a large compromise. It would be desirable to submit each lot of forgings to an annealing cycle best suited to the particular combination of machining operations intended, but the advantage from the machining standpoint would be outweighed by the cost of multiple annealings. Furthermore, in a plant handling many lots of forgings in small quantities with different combinations of machine operations, it is not practicable to set up different annealing cycles; the loss of furnace time for adjustment between batches would more than offset machine shop savings. Therefore, for usual conditions of operation, the best compromise between hardness and structure will be most economical.

Experience with boron steels indicates that a partially spheroidized pearlitic structure and hardness in the range of C-15 to 22 will give good average machinability for most classes of work. Most important, this condition is readily obtained by the heat treatment outlined. Experience has also indicated that machining operations can tolerate a wider range of structures and hardnesses. As is also true for the straight carbon steels, the requirements upon the annealing procedure are not so critical as they are for other common alloy steels.

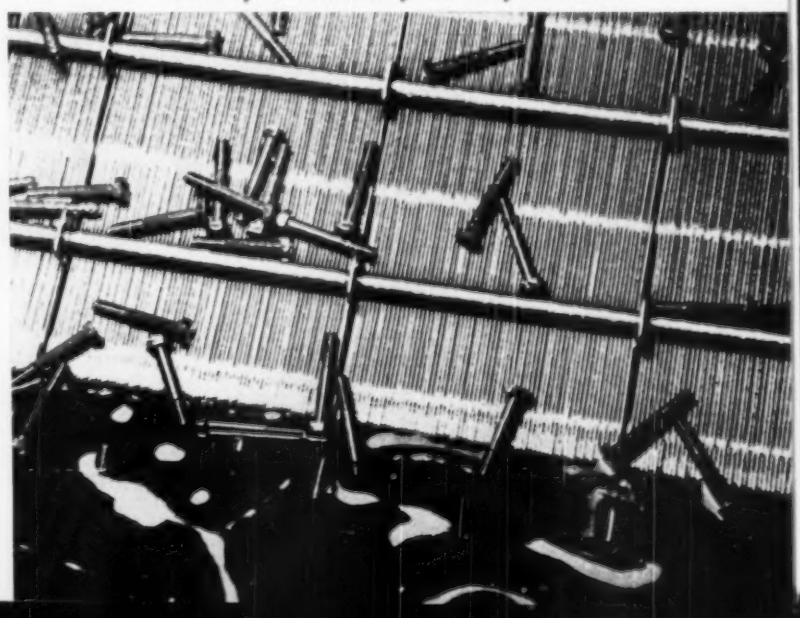
Confining attention now to the handling of cold finished material, by far the largest percentage of machined parts made therefrom start out as turned blanks. As with forgings, the most desirable metallurgical condition for the various machining operations is never the same. As pointed out by the present author in an article in *The Iron Age* for March 21 and 28, 1946, the problem is complicated by operating variables, and further by the techniques employed at the mills, especially with respect to annealing for cold drawing. The net result is that specifications must reflect an *average* metallurgical condition — a compromise between all of the machinability requirements and the range within which the mills are able to produce. Such a specification is neither precise nor ideal, but these are the conditions that prevail, and the boron steels must be considered with the same qualifications that apply to other grades.

## Boron Steel Treated With Sodium Sulphite

Promising reports on steel treated with sodium bisulphite (a development* of the Wisconsin Steel Division of the International Harvester Co.) prompted some experimental runs. Results were so encouraging that the material was subsequently specified as standard for plant No. 2. The principle of the treatment is that sodium bisulphite, when added to the steel, breaks down into sodium oxide and sulphur dioxide. The sodium oxide reacts with the oxides in the heat, forming a fusible slag, and thus purges the metal of inclusions detrimental to tool life. The originators of the process noted that there is no effect on mechanical properties or grain size control in the lower sulphur ranges; it is also possible that elimination of nonmetallics might result in improved fatigue life.

*See *Metal Progress*, October 1947, p. 565.

*Modern Manufacture Needs Ready Machinability and Uniform Hardenability — Photo by Van Fisher*



Consumption of some 5000 tons of boron steel indicated that it machines approximately the same as the lean alloys previously used, except that the finish obtained has been somewhat better. Normally it would be expected that the boron steel, with its lower alloy content, would enjoy some advantage; however, the effects of normal variations in microstructure, plus a multitude of normal operating variables, have masked whatever difference exists.

In investigations aimed at improving machinability of the boron steel through specification of the annealing treatment, we have noted that a wide range of grain sizes may often occur from one heat to another. Also microstructures may vary from 100% lamellar pearlitic to 100% spheroidized. Such conditions have been noted to occur occasionally in all commercial grades.

In controlled tests at Plant No. 1, some short runs on a sulphite-treated boron steel in a screw machine gave some data in fair agreement with operating experience elsewhere.

**Table I — Screw Machine Operating Data for Boron Steel (B) and Sulphite-Treated Boron Steel (S)**

Machine: New Britain Automatic, Model 61, 1⅝ in., 6 spindle

| Test: | 4A | 4B | 4C | 5 |
|---|---|---|---|---|
| Part | 5428 | 5428 | 5428 | 5428 |
| Steel | S | S | S | B |
| Hardness | C-16 to 18 | C-16 to 18 | C-16 to 18 | C-13 to 16 |
| Diameter of cold drawn bar | 1⅜ in. | 1⅜ in. | 1⅜ in. | 1⅜ in. |
| Pieces per hour | 232 | 232 | 248 | 190 |
| Pieces per tool grind | 1393 | 500 | 248 | 1393 |
| Tool life in hours | 6 | 2 | 1 | 7 |
| Surface feed (ft. per min.) | 131 | 140 | 149 | 109 |
| Feed per revolution: Tool slide | 0.0062 | 0.0050 | 0.0050 | 0.0062 |
| Cutoff | 0.0020 | 0.0018 | 0.0018 | 0.0018 |

**Table II — Screw Machine Operating Data for A9440 and Two Heats of Boron Steel**

| Test: | 1 | 2A | 2B | 3 |
|---|---|---|---|---|
| Part | 5447-M | 5447-M | 5447-M | 5550 |
| Steel | A9440 | Boron steel | Boron steel | Boron steel |
| Hardness | C-15 to 17 | C-17 to 19 | C-17 to 19 | C-17 |
| Diameter of cold drawn bar | 1⅝ in. | 1⅝ in. | 1⅝ in. | 2⅛ in. |
| Pieces per hour | 26 | 26 | 20 | 53 |
| Pieces per tool grind | 156 | 39 | 80 | 318 |
| Surface feed (ft. per min.) | 108 | 84 | 84 | 120 |
| Feed per revolution | 0.0013 (form tool) | 0.0013 (form tool) | 0.0013 (form tool) | 0.005 (drills) |
| Machine | New Britain Gridley — 1⅝ in., 6 spindle | | | Acme* |
| Machinability | Satisfactory | Unsatisfactory | Unsatisfactory | Satisfactory |

*Acme Gridley, 3½ in., 6 spindle.

Table I is a *résumé* of the results. Parts, tooling, machine and operator were the same in all. In Test 4a the material was sulphite treated and in Test 5 the material was regular boron steel. The setup was such that the operation produced 1393 pieces per tool grind on both materials, but the production in pieces per hour was 22% greater with the sulphite-treated material.

Tests 4b and 4c show the effect of increasing the cutting rate on sulphite-treated material. The sharp decrease in tool life is noted, resulting in more downtime and less production, and indicating that the results from Test 4a are more representative of top machine efficiency.

Table II contains more test results which indicate that difficulties in machinability may occur in the boron steel. Tests 1 and 2a, comparing A9440 and boron steel, show that at equal production rates the former gave nearly four times the number of pieces per tool grind. Even at reduced cutting speeds, Test 2b, the tool life on this material was poor. In Test 3, using another heat of boron steel, the results were very much better, with twice as many pieces per tool grind at higher speeds than those shown in Test 1 for A9440. This discrepancy between the machinability of the two lots of boron steel was traced to their microstructures, illustrating the former remark concerning variations in structure due to mill techniques. However, the results of Test 3 are generally more typical of our experience with boron steel on screw machines.

Numerous processes may be interposed between the initial forging (or machining) and the final significant operation — heat treatment. Some, involving hot work, occasionally give trouble when the operating temperature exceeds the recrystallization temperature. Or, an undesirable air hardening effect may be noted; in that event a 20-min. tempering at 1250° F. will satis-

factorily correct the condition. Boron steel reacts normally in such miscellaneous processes.

Experience indicates that where the mechanical properties developed in the material through heat treatment are satisfactory, worth-while advantages will be gained in the other operations. This fact we have tried to develop in the preceding part of this paper.

## Heat Treatment for Physical Properties

Maximum properties of any material depend upon suitable heat treatment. Many metallurgists overgrade their materials to provide a margin for expected irregularities in heat treatment, a practice most notable where the application calls for a carbon steel or a steel "just a little better". Owing to the somewhat erratic response of carbon steels to heat treatment variations, when such a borderline condition is encountered a switch to a 0.40% carbon alloy steel will effectively solve the heat treatment problem, but at a cost. Such

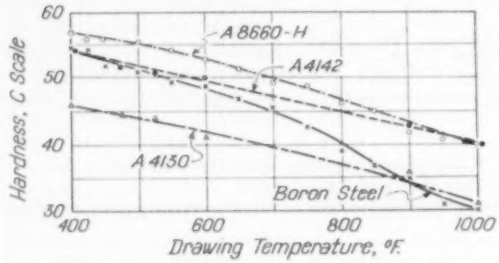



*Fig. 4 — Drawing Temperature for Higher Hardness Is About the Same for Both A 4142 and 1045 Boron Steel, But Drawing Temperatures Are Similar to A 4130 for Softer Ranges*

increased costs are, of course, not allowable if there is some other solution to the problem. The search, therefore, is for a metal with an ample hardenability, capable of providing the necessary mechanical properties for success in field service, and yet permitting the most economical fabricating operations with a consequent low-cost production. It has been previously shown that the boron steels are more economical to machine in production operations than the lean alloy steels which had previously been used.

Production heat treatment of several thousand tons of this steel has conclusively established that it is well suited to production shop heat treatments in either conveyerized furnaces or batch furnaces. It is relatively insensitive to minor variations in quenching temperatures, developing full surface hardness (approximately C-55) when quenched from 1525° F., and producing satisfactory properties even when quenched at somewhat higher temperatures. Overheating in hardening — up to 1625° F. — does not result in cracking or excessive grain growth when the heating cycle is of minimum duration (merely sufficient for through heating). Coarsening of the structure naturally occurs at prolonged temperatures. Long soaking periods at hardening temperatures decarburize and scale to about the same extent as is encountered with straight carbon steels; in suitable conveyer furnaces, decarburization is less than a half a thousandth.

Tempering temperatures for boron steel have been found to be slightly lower, generally, than those required for other lean alloys. Figure 4 shows comparative drawing curves for four such steels. It will be noted that the indicated temperature to produce C-48 and up is about the same for both the boron steel and A 4142, but at the lower hardnesses — below C-42 — there is over 150° F. difference.

## Field of Application

Thus far no phenomenal advantage of boron steel has been shown, but rather it has been established that it possesses certain characteristics that place it within the list of lean alloys — so far as

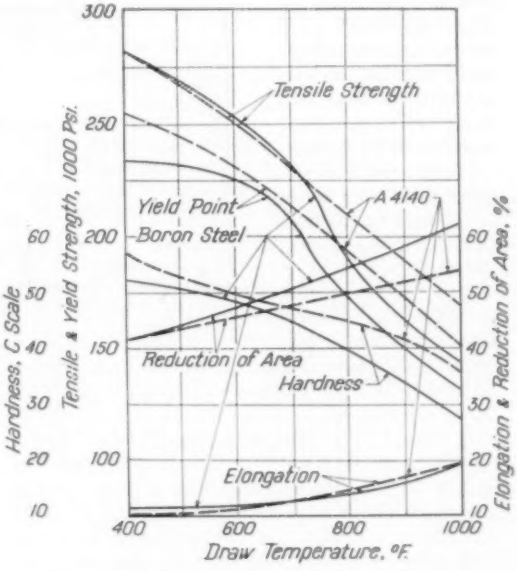



*Fig. 5 — Mechanical Property Chart of Boron-Treated 0.45% Carbon Steel and Standard A 4140*

properties and hardenability are concerned. It has reliable hardenability and heat treating characteristics, and (in proper application) processing advantages over steels of higher hardenability. It bridges the gap between straight carbon steels and lean alloys, enabling the metallurgist to specify a material that will fulfill his requirements more closely than either of the conventional types.

Along with the field service and manufacturing experience which have been collected, a program of testing extending over several years has confirmed the reliability of the boron steels, and furnished data for predicting the possibilities outside the present applications. Clarification of the principles of hardenability has done much to redirect the emphasis formerly placed upon the mechanical properties chart, but for the benefit of those accustomed to selecting a material on the basis of reported specific properties, such a chart has been prepared in Fig. 5. It also shows the mechanical properties for A4142, thus correlating their properties at equal hardnesses.

**Table III — Comparative Tensile Test Results on T-Bolts of Boron, A4340 and A4140 Steels**

| Material | Rockwell Hardness | Ultimate Strength | |
|---|---|---|---|
| | | Predicted | Actual |
| Boron steel | C-42 | 215,000 psi. | 204,000 psi. |
| | C-42 | 215,000 | 208,000 |
| | C-46 | 240,000 | 230,000 |
| | C-45 | 240,000 | 238,000 |
| A4140 | C-41 | 215,000 | 210,000 |
| | C-41 | 215,000 | 203,000 |
| | C-45 | 235,000 | 251,000 |
| | C-46 | 235,000 | 240,000 |
| A4340 | C-42 | 215,000 | 213,000 |
| | C-44 | 215,000 | 217,000 |
| | C-46 | 240,000 | 260,000 |
| | C-46 | 240,000 | 258,000 |

Figure 6 contains the result of notched-bar tests (Charpy), and indicates that the boron-treated steel is indistinguishable from A8660-H (0.85 Mn, 0.50 Cr, 0.50 Ni, 0.20 Mo) at equal hardnesses.

Destructive tests have been conducted upon many products made from boron steel. In one such examination, samples were taken from a production run of forged T-bolts. The bolt consisted of a 6-in. leg and a 2-in. cross member, both ¾ in. in diameter. Samples made of A4340 and A4140 bolts were included in the order and tested simultaneously in full section. Results are shown in Table III. The actual values correspond closely to the predicted, based on hardness, and reaffirm the previous statements concerning the reliability of the material.

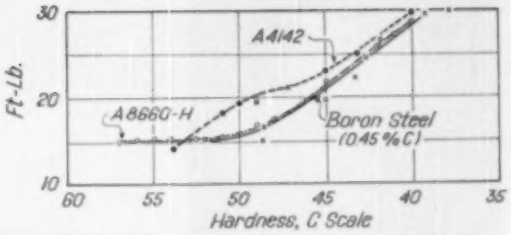



*Fig. 6 — Charpy Impact Tests on Comparable Low-Alloy Steels at Various Hardness Levels*

In other service tests, several parts designed to resist torque were investigated. Parts of various analyses and identical design were subjected regularly to torque loads as part of production testing. In Table IV the results of these tests have been collected in such a way as to provide ready comparison. The boron steel is obviously as suitable for such loadings as any of the comparable alloys.

None of the data here presented or known to the authors indicate that boron steels could entirely replace any of the alloys which over many years of use have come to be considered standard. It is obvious, too, that it should be specified only with full knowledge of what field service conditions for the part may be. In the production of steel parts where material costs represent a large portion of final cost, or where fabrication and production cost is a factor or is the source of troublesome problems, boron steels may very well provide some answers of interest metallurgically. Admittedly, the field of application of boron steel is a limited one, but within its sphere of adequacy it is obviously an economical and practical steel.

The authors are aware of other applications outside of their own where boron steels are acquitting themselves successfully, but no specific facts about them are available to us. Additional work among interested parties is constantly going forward and will gradually build up a useful fund of information.

**Table IV — Test Results on Some Typical Torque Members Hardened to C-46**

| Nominal Size | Torque at Failure (In-Lb.) | | | Federal Specification |
|---|---|---|---|---|
| | Boron Steel | A8640 | A4140 | |
| 7/16 | 3300 | 3000 | 1950 | 650 in-lb. |
| ½ | 4650 | 4100 | 3550 | 1020 |
| 9/16 | 5350 | — | 4850 | 1500 |
| ⅝ | 6000+* | 6000+* | 6000+* | 2600 |

*Limit of testing equipment.

# Movements Among Metallurgists

*Charles R. Cox*

**Charles R. Cox**, who presented the principal banquet address at the last National Metal Congress and Exposition, and who has spent his working life since 1920 in the steel industry, becomes president of Kennecott Copper Corp., the world's largest copper producer, succeeding the late E. T. Stannard. Mr. Cox has an exceedingly wide acquaintance among metallurgists, operating men and business men, having a remarkably retentive memory for names and faces. From 1920 to 1930 he was with Crucible Steel Co. of America, then for four years works manager for Babcock & Wilcox Tube Co., then joining National Tube Co., becoming its president nine years later in 1943, and president of Carnegie-Illinois Steel Corp. in 1946.

**Bernard Trock**, formerly with the Timken-Detroit Axle Co., is now employed at the Detroit Arsenal as a materials engineer.

**Clement L. Bissonette, Jr.**, a recent graduate of the University of Minnesota, is now employed in metallurgical and product development division of the Aluminum Cooking Utensil Co., New Kensington, Pa.

**Henry O. J. Hanzlik** has been transferred to the Kansas City works of Westinghouse Electric Corp. to be in charge of the metallurgical section. He was formerly in the Aviation Gas Turbine Div., South Philadelphia.

**Frederick I. Brown, Jr.**, who graduated from Massachusetts Institute of Technology in June 1949, is now metallurgist for the Arkansas Foundry Co., Little Rock, Ark.

*Clifford F. Hood*

An American success story will probably be written about the rise, from clerk to president in 21 years, of **Clifford F. Hood**, who now is to be head of Carnegie-Illinois, the principal steel producing subsidiary of U. S. Steel Corp. A graduate electrical engineer from University of Illinois, he went to work at the Worcester plant of American Steel & Wire Co. in 1919, rising through various positions to become manager of operations in the Worcester district in 1933, and president of the company in 1938 with headquarters in Cleveland. "Steel & Wire" is said to be the largest single employer of labor in metropolitan Cleveland, and in Mr. Hood's presidency he has taken a notable part in civic affairs.

**C. K. Eggleston**, previously vice-president of engineering for the Barnes Mfg. Co., has been named vice-president in charge of manufacturing of Non-Ferrous Perma Mold, Inc., Mansfield, Ohio.

**Wynn F. Rossiter**, formerly New England sales manager, has been appointed assistant vice-president of Carpenter Steel Co., Reading, Pa.

*Harvey B. Jordan*

**Harvey B. Jordan** succeeds Clifford Hood as president of American Steel & Wire Co. For the last 10 years he has been vice-president in charge of operations of that company, previously having been head of the metallurgical department. Mr. Jordan joined the company 35 years ago, immediately after graduating from Pennsylvania State College, where he majored in industrial engineering. His first work was as chemist at the Central Furnaces in Cleveland; he steadily grew into larger responsibilities, rising to superintendent 15 years later, in 1929. In five more years he was promoted to head the metallurgical department of the entire company. His intimate acquaintance with all phases of production, from blast furnace, through open-hearth and wire mill, have solidified his reputation as one of the leading operating metallurgists in the American steel industry.

**Creston E. Kite**, formerly vice-president in charge of sales of General Alloys Co., has been named general manager of the Unistrut Eastern Service Co., Irvington, N. J.

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## Personals

**C. F. Johnson** has been appointed manager of valve sales of Manning, Maxwell and Moore, Inc., Bridgeport, Conn. Mr. Johnson has been with the company for the past year.

**Donald R. Malthaner** has been transferred from the Chevrolet-Detroit Forge to the Chevrolet-Cleveland plant as assistant to the chief metallurgist. He was an August 1949 graduate of University of Notre Dame.

**Henry Lipsey**, formerly with Mercast Corp., is now northern Ohio representative for Coast Metals, Inc., with offices in Cleveland.

**Earl W. Swarens**, recently graduated from Michigan College of Mining & Technology, has taken a position as metallographer at the metallurgical laboratory of Chevrolet Div. of General Motors Corp., Detroit.

**Henry Stirling Blair, Jr.**, a recent graduate of Rensselaer Polytechnic Institute, is now assistant metallurgist at Curtiss Wright Corp.'s Propeller Div., Caldwell, N. J.

**Elmer A. Terwell**, formerly sales engineer for Driver-Harris and previously associated with the Salkover Metal Processing Co., is now representing Rolock, Inc., Fairfield, Conn., throughout northern Illinois and southern Wisconsin.

**E. L. McReynolds** has been appointed sales engineer specializing in the sale of alloy and stainless steel strip for Sharon Steel Corp., Sharon, Pa. He was recently with Morse Chain Co., Ithaca, N. Y., and had been previously with Republic Steel Corp., Massillon, Ohio.

**Vincent Frick** has been transferred by Westinghouse Electric Corp. from the Aviation Gas Turbine Div., South Philadelphia works, to the Kansas City works, where he will be in the metallurgical laboratory.

Rolock, Inc., Fairfield, Conn., announces that **B. M. Brownell** will handle its accounts throughout Missouri as well as in southern Illinois, and that **W. G. Barstow** will be its representative in Minnesota, northern Wisconsin and northern Iowa.

**Gale S. Hanks**, **David E. Deutsch**, **Richard C. Neal** and **John B. Schroer** have recently joined the chemistry and metallurgy division of the Los Alamos Scientific Laboratory of the University of California. Mr. Hanks was formerly with the Kennecott Copper Co., McGill, Nevada; Captain Deutsch is on temporary loan from the United States Air Force; Mr. Neal was formerly at the University of Illinois; and Mr. Schroer was previously with the Zia Co., Los Alamos, N. M.

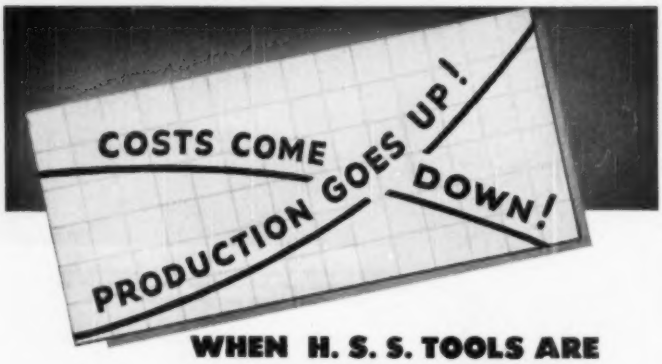
**Charles E. Stevens, Jr.**, formerly chief engineer of the Al-Fin Div., Fairchild Engine and Airplane Corp., is now plant manager of Chicago Railway Equipment Co., Chicago.

**R. J. Perry**, formerly service manager of toolsteels for Boyd-Wagner Co., has set up a small forging shop in Ingalls, Mich.

**Ernest S. Kopecki**, previously metallurgical editor of *Iron Age*, has accepted a position with Pennsylvania Salt Co., Philadelphia.

Kaiser Steel Corp. announces that **Harry H. Beyma** has been appointed manager of cold rolled steel sales. Mr. Beyma has been with Kaiser since 1944 as a sales representative in southern California.

**L. I. Stead**, who has been with Youngstown Sheet and Tube Co.'s Chicago district since 1918 as chemist, laboratory foreman and assistant chief chemist, has been recently appointed chief chemist.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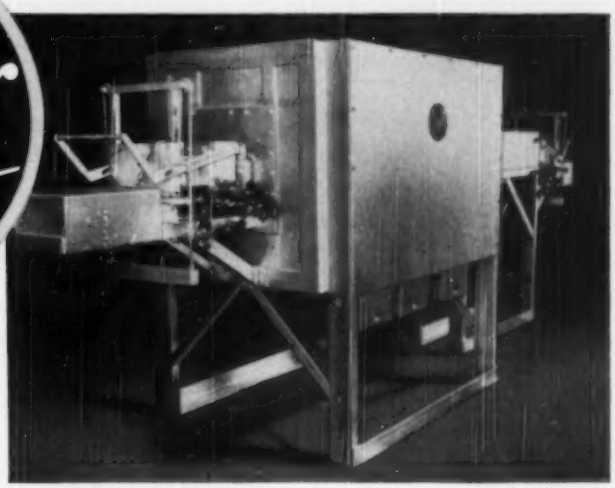

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## A New Boron Steel*

THE PAPER presented by Bardgett and Reeve at the fall meeting in 1949 of the Iron and Steel Institute in London must be regarded as an important contribution to steel metallurgy, since, in addition to providing what is probably the best solution so far proposed of the problem of manufacturing a weldable steel with high yield point, it introduces one of the first boron-containing steels of real industrial importance and illustrates how critical may sometimes be the conditions required to give desirable properties. It is shown quite definitely that within certain ranges of carbon, molybdenum and boron contents, ranging about a typical composition of 0.14% carbon, 0.40% molybdenum and 0.003% boron, it is possible to obtain (in the hot rolled and normalized condition) a yield point of more than 67,500 psi., and a maximum stress of 85,000 psi., combined with a high reduction of area, high notched-bar toughness, and exceptionally good weldability. The mechanical properties of this steel in the as-rolled condition are comparable with those normally obtained in steel in the hardened and tempered condition; the weldability is, to some extent, comparable with that of mild steel.

*Abstracted from "Mechanical Properties of Low-Carbon, Low-Alloy Steels Containing Boron", by W. E. Bardgett and Dr. L. Reeve, *Journal* of the Iron and Steel Institute (London), Vol. 163, November 1949.

Mechanical tests were carried out on several series of steels, all having carbon contents within the range 0.04 to 0.18%, made in an 18-lb. high-frequency furnace and tested in the form of normalized ⅝-in. round bar. Small additions of molybdenum to a steel containing from 0.05 to 0.14% C and about 0.003% B had only a small effect on the mechanical properties, but when about 0.30% Mo was added there was a striking increase in both maximum stress and yield stress; a still greater increase was observed when the molybdenum content was raised to 0.40%. A steel containing 0.14% C and approximately 0.40% Mo with 0.0016% B had a maximum stress of 86,000 psi. and a yield stress of 75,000 psi., with good ductility and toughness.

The corresponding figures for a boron-free steel of similar composition were 68,000 and 38,000 psi. respectively. Thus the yield stress was doubled by the addition of 0.0016% boron.

Steels containing small amounts of nickel or chromium or vanadium, in the absence of molybdenum, were practically unaffected by the addition of such small amounts of boron, but the critical molybdenum content — that is, the content at which the maximum stress and yield stress showed a rapid increase with increase in molybdenum — was lowered to about 0.20% Mo in steels containing boron together with either 2.0% Ni or 1.0% Mn, and to about 0.25% Mo in steels containing 1.0% Cr. With 1.5% Mn or 0.5% Cr in the presence of boron, the maximum stress and the yield stress increased gradually yet markedly with increase in molybdenum content.

While substantial increases in maximum stress and yield stress occurred in these low-alloy steels containing boron when the molybdenum content was increased above a certain figure, the steel possessing the most attractive properties was the molybdenum-boron steel containing about 0.14% C, about 0.40% Mo, and about 0.003% B. *(To p. 96)*

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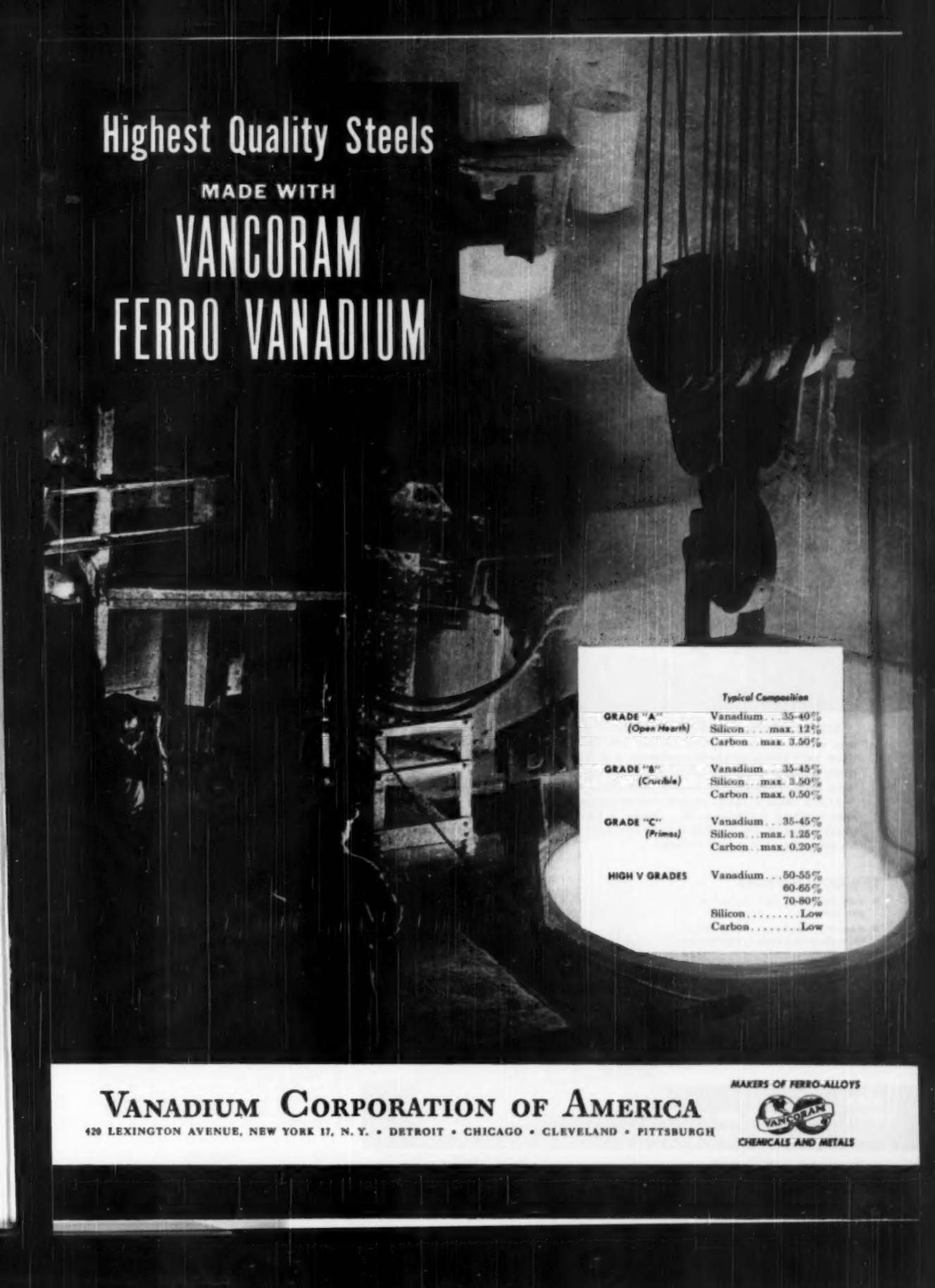


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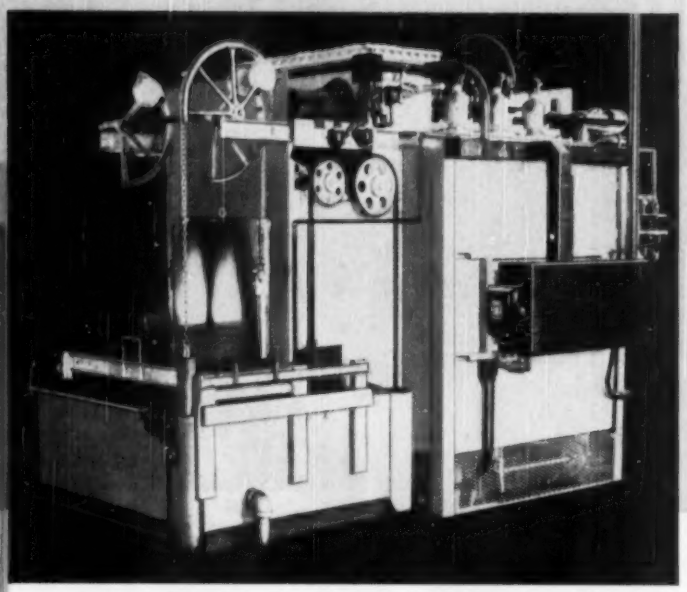

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## A New Boron Steel

*(Continued from p. 94)*

The question of mass effect has not been fully explored, but the results indicate that plates 2 in. thick (and probably greater) will yield the high properties referred to, provided the acid-soluble boron does not fall below about 0.0013 nor rise above about 0.007%.

Production heats of low-carbon, molybdenum-boron steel, made in high-frequency and basic open-hearth furnaces, have confirmed these high ultimate and yield stresses. There has been no difficulty in introducing the desired quantities of boron by additions to the ladle, and the boron has been uniformly distributed throughout the ingots. Oxygen and nitrogen contents, however, have to be watched, else boron additions are ineffective. TOM BISHOP

## High-Temperature Fatigue Testing*

THE Ural Turbine Works has systematically investigated the high-temperature fatigue strength of materials for turbine construction. These materials have included high-chromium stainless steels for turbine blades, chromium-molybdenum, chromium-nickel-molybdenum, and other alloy steels for turbine disks, valves, and other parts. In order to complete this work it was necessary to develop an adequate testing procedure from the various methods recommended by previous investigators. This paper considers the fatigue testing of rotating cylindrical specimens at temperatures up to 1100° F.

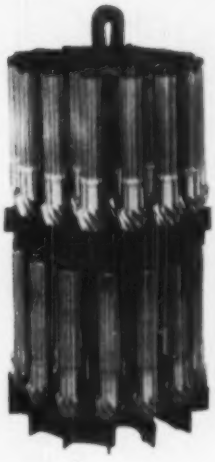
A Schenk universal 5000-r.p.m. machine (similar to an R. R. Moore fatigue tester) was used. Surrounding the working area of the specimen was an electric furnace with four separately controlled sections. The furnace had constantan wire heating elements, a ceramic muffle, and a metal casing. To protect the bearings from overheating they had a continuous supply of cold oil and were shielded from the furnace heat by asbestos disks.

The temperature of the speci-

*(Continued on p. 98)*

*Abstracted from "Method of Testing the Fatigue of Steel Samples at High Temperatures", by M. F. Sichikov and Z. D. Vishnevetzkii, *Zavodskaya Laboratoria*, Jan. 1948, p. 86-91.

# JOB PROVEN IN INDUSTRY



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## High-Temperature Fatigue Testing

*(Continued from p. 96)*

men can be measured directly by placing the thermocouple in an axial hole in the specimen and taking off the potential leads by sliding contacts. However, the method is difficult and unreliable. The indirect method developed in this work relates the temperature of the space inside the furnace to the specimen temperature. The measuring thermocouple is placed on the center line of the muffle halfway between the heating element and the specimen surface. Calibration curves for various temperatures and specimen velocities were obtained using carefully controlled sliding contacts from a thermocouple soldered on the specimen. The specimen temperature was about 360° F. below the furnace temperature at 0 r.p.m. and about 180° F. below at 5000 r.p.m. The temperature uniformity of the working area of the specimen was confirmed by the uniformity of the temper colors.

It was found that a cylindrical specimen could be used instead of a conical one. This cylindrical specimen is the one ordinarily used at room temperature and has a parallel section about 3.2 in. long and 0.30 in. diameter, with enlarged ends for gripping.

The Wöhler method of fatigue testing was used except that $5 \times 10^6$ cycles was found to be adequate rather than $10^7$ cycles. It was expedient to calculate an approximate fatigue stress value using the equation of Houdremont and Mailänder,

$$\text{Fatigue strength} = 0.25(\text{T. S.} + \text{Y. S.}) + 7000 \text{ psi.}$$

where the tensile strength and yield strength are determined at the temperature in question.

## Beryllium Hazards*

THIS survey of conditions existing in late 1946 in a plant manufacturing commercially pure beryllium and beryllium-copper

*(Continued on p. 100)*

*Abstract of "Analysis of Dust and Fume Hazards in a Beryllium Plant", by Sidney Laskin, Robert A. N. Turner, and Herbert E. Stokinger, Department of Industrial Hygiene, University of Rochester. Document MDDC-1355, Atomic Energy Commission, Technical Information Branch, Oak Ridge, Tenn.

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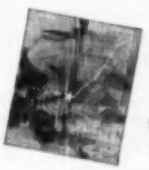

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## Beryllium Hazards

*(Continued from p. 98)*

alloy was correlated with medical history of workers (averaging 113 in number) during 1943-1946 inclusive. In that time 136 cases of beryllium poisoning were recorded, about 140 cases per million man-hours of exposure. (An acceptable number in well-established chemical industries is 4.) Prior to 1943 the plant had experienced relatively little trouble, but increase in intensity of operations with the outbreak of the war, together with loss of trained and selected personnel by the operation of the draft, may be listed as possible factors responsible for an epidemic effect.

The operations involve grinding beryl ore, sintering, conversion to the sulphate with sulphuric acid, furnacing to the oxide, treatment of the oxide by acid fluoride followed by a reduction of the beryllium fluoride to yield metallic beryllium. The beryllium-copper alloy is made by heating copper with beryllium oxide in the presence of carbon. The atmospheric contamination associated with these processes is in the form of dusts, fumes, and mists.

Of the areas surveyed, those of the beryllium fluoride and beryllium metal furnaces showed the largest concentrations of beryllium and fluoride. Most arresting was the disproportionately high fluoride concentration near the fluoride furnace, which may represent a hazard in itself. Concentrations a thousandfold that of beryllium were found.

Another problem investigated was that of beryl ores suspected of containing radioactive impurities. One of three suspected ores contained 4.0% uranium, 0.4% thorium and 0.4% lead, and showed enough beta activity to suggest that uranium or other radioactive materials may act as predisposing agents in beryllium poisoning.

A summary of the processes, potential hazards and health history of the various departments in this plant is as follows:

In the grinding and sintering department the major potential hazard is ore dust (beryl or $3\,BeO \cdot Al_2O_3 \cdot 6\,SiO_2$) and one worker endured a hospital case of long duration ascribed to silica fumes.

In the ore treatment department, where the sintered ore is converted to sulphate with $H_2SO_4$ and crys-

*(Continued on p. 102)*

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## Beryllium Hazards

*(Continued from p. 100)*

tallized, the hazards are ore dust, acid mists, and beryllium sulphate. Numerous respiratory cases occurred in 1943 (one fatal) but these were reduced to zero in 1946 by enclosing the various operations, and by increased vigilance by the company's medical staff. However, dermatitis (to be described in some detail) continued steady at about six per year.

Beryllium oxide is produced from the crystallized sulphate in a calcining furnace. Potential hazards are dust particles of beryllium sulphate, ammonium sulphide and beryllium oxide. Health history of this region is good; nothing more than very minor dermatitis was recorded.

Beryllium-copper alloy is produced by furnacing beryllium oxide, carbon and copper. No skin troubles were reported from such operations; six respiratory cases (three fatal) occurred in 1943 and 1944 and none in 1945 and 1946.

Beryllium oxide is treated with acid fluoride and converted into $(NH_4)_2\,BeF_4$, which is heated and changes to beryllium fluoride, $BeF_2$. The latter is reduced to metal by further furnace treatment.

Manifestations of beryllium poisoning where beryllium fluoride is the predominant compound are most numerous. Dermatitis cases ranged from 5 in 1943 to 19 in 1946, a total of 42; 23 respiratory cases were recorded causing from 3 to 150 days lost time. Major potential hazards are thought to be acid fluoride and beryllium fluoride* mists.

In the area devoted to reduction to beryllium metal the workmen have had no skin troubles; three respiratory cases (with 6 to 14 days lost) were recorded in 1946.

The skin troubles observed were all on patients exposed to atmospheres containing beryllium sulphate or beryllium fluoride, and consisted of contact dermatitis [inflammation of the sensitive layer below the outer skin] and skin ulcers. Contact dermatitis was often severe, occurring most frequently on exposed regions of hands, arms, face and neck. The small round eruptions contained

*(Continued on p. 104)*

*Beryllium fluoride is used as a collective term to include other fluorides of beryllium, such as ammonium-beryllium fluoride complexes and beryllium oxyfluoride.

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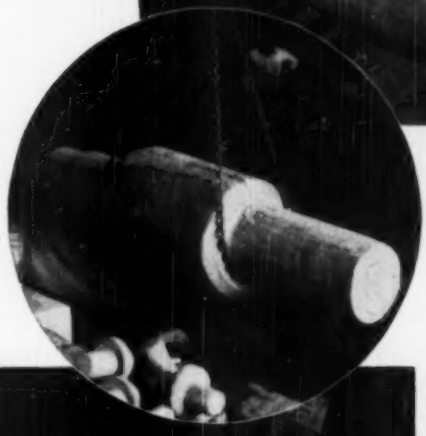
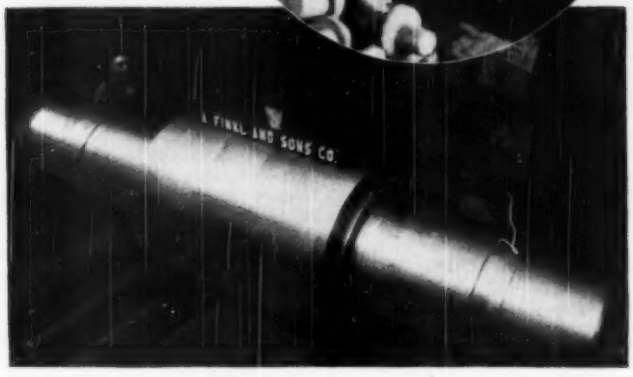


*One of two 15 ton helical gear blanks in various stages of production: after forging and iso-thermal treatment; lowering into water quench; rough machined after complete metallurgical inspection and approval.*

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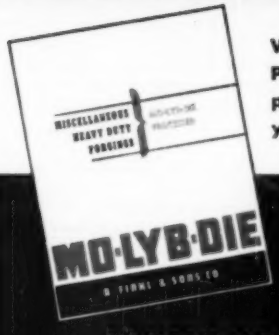


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## Beryllium Hazards

*(Continued from p. 102)*

fluid; when the disease attacked the face, conjuctivitis [inflammation of the inner surface of the eyelid] was invariably present. Frequently an ailment of the upper respiratory tract was also observed.

Skin ulcers occurred in the same industrial operations as the above. The prerequisite appears to be a small skin abrasion into which a particle of beryllium sulphate or fluoride became embedded. The skin tended to heal over this particle and form a pimple which then developed into a small abscess. They were single, as a rule, and caused little distress unless infected or located near a joint. Healing did not occur until the crystal and the fibrous base of the ulcer were removed surgically.

Respiratory tract manifestations occurred in various regions, the nose, trachea, bronchial tubes and lungs. Inflammation of the nose and head passages occurred among furnace tenders where beryllium sulphate or fluoride was heated. The chief complaint was soreness of the nose and throat, and blood clots being blown from the nose. As a rule there was no cough.

Inflammation of the trachea and bronchial tubes [windpipe] also affected the above-mentioned furnace tenders, and sometimes was accompanied by inflammation of the head passages. The patients had a cough, with occasional bloody sputum, and rales [scraping sounds] in both lungs. X-rays were normal. Complete rest was required for a cure.

Severest form of beryllium poisoning was pneumonia. Four deaths are ascribed to this cause; many complete recoveries are recorded. Chemical pneumonia developed in workers on many different jobs under varying conditions, and no single cause or operation can be isolated as responsible. Typical symptoms were as for bronchial troubles (above), plus short breath, increasing fatigue, rapid pulse, low fever. Signs of infection were conspicuously absent. X-rays and blood counts were normal for two or three weeks after onset of symptoms.

Records are insufficient to determine whether age, sex or period of employment has any influence on susceptibility of workers. Incomplete records on case histories also prevented an analysis in terms of specific occupations.

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# Infiltrated Alloys*

COLD COMPACTING of metal powders and sintering by the customary powder metallurgical technique leads to porous materials in which most of the pores are intercommunicating. When such porous bodies are impregnated with oil the well-known self-lubricating bearings are obtained. The idea of using liquid metals instead of oil as impregnants for filling the pores of a sintered metal skeleton was suggested in early patents more than thirty years ago. [For enumeration of early work see the article on p. 64.]

No definite rules can be formulated that tell which alloys can be prepared by infiltration. However, there are certain conditions that are necessary or favorable for impregnation:

1. The melting points of the two components should be as far apart as possible.

2. The solubility of the components in each other at room temperature should be as small as possible. If they are soluble, it is advantageous to have a solubility decreasing strongly with temperature.

3. During infiltration, no eutectics, solid solutions or other intermediate phases should be formed that may hinder the penetration of the pure impregnating metal by increasing its volume or viscosity.

4. The infiltration temperature should be as close as possible above the melting point of the infiltrating metal in order to keep down any possible solution of the skeleton metal in the impregnant.

5. The infiltration time should be short, particularly when the metals have limited solubility in the liquid or solid state.

6. Oxide skins on the skeleton metal are to be carefully avoided.

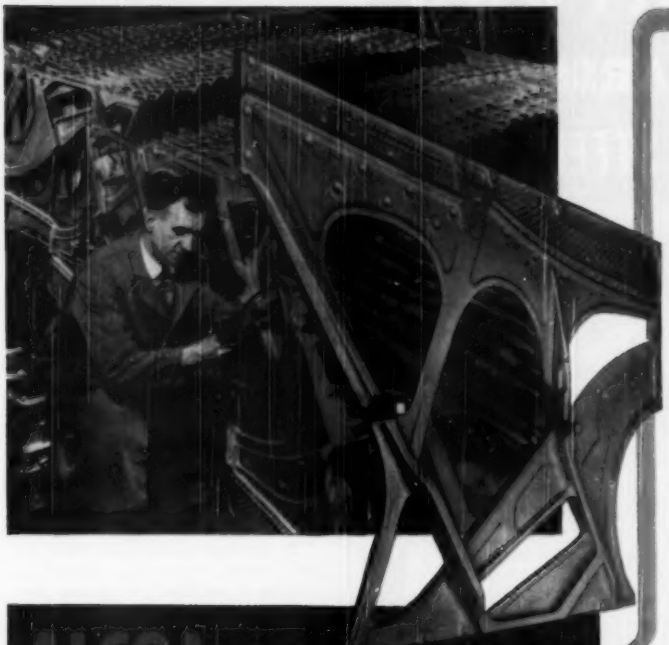
7. Metals whose oxides cannot be reduced in hydrogen are to be introduced as master alloys.

8. Infiltration in a vacuum leads to complete infiltration even if the infiltrating metal wets the skeleton metal poorly.

9. If the infiltrating metal alloys with the skeleton metal, it is preferable to use as infiltrant an

*(Continued on p. 108)*

*Abstracted from "The Preparation and Properties of Infiltrated Alloys", by R. Kieffer and F. Benesovsky, *Berg- und Hüttenmännische Monatshefte*, Vol. 94, 1949, p. 284.



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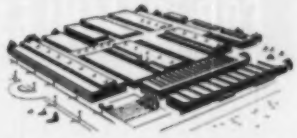

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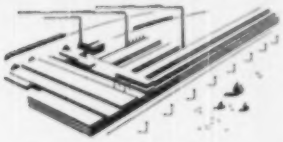

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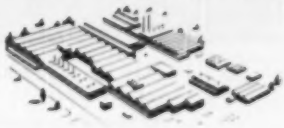

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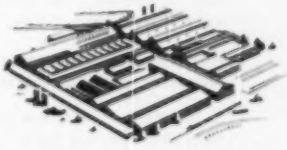

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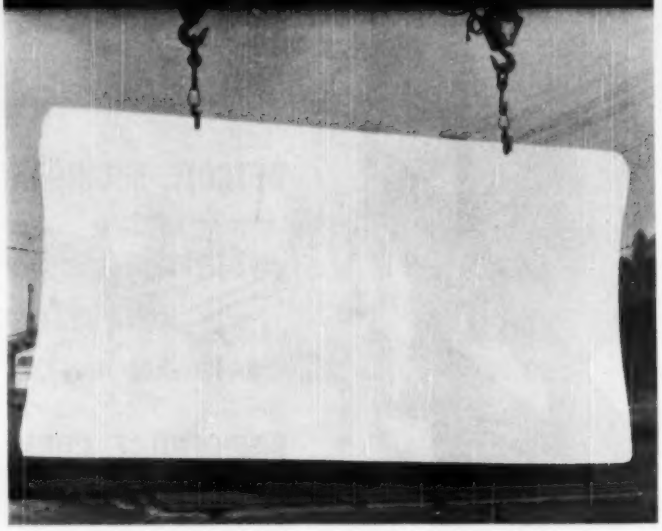

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## Infiltrated Alloys

*(Continued from p. 106)*

alloy which corresponds to the equilibrium composition at the infiltrating temperature.

10. Heat treating after infiltration, either for homogenization or for improving physical properties, must be below the solidus temperature of the alloy system.

In addition to these metallurgical requirements certain physical properties of the alloy system must also be considered; the most important of these is the interfacial tension between the components, generally called the wetting properties. Because of the lack of sufficient data on interfacial tensions, the approach to the study of "melt-porous body" systems has been largely empirical.

Five groups of infiltrated alloys have become commercially important during the last 15 years:

1. Contact materials on the basis tungsten-copper, tungsten-silver, molybdenum-copper and molybdenum-silver.

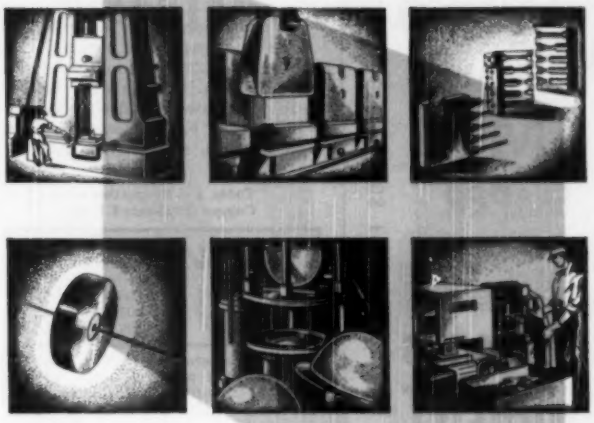
2. Bearing materials. The engine bearing material produced by brazing a mixture of copper and nickel powders onto a steel strip to form a metal sponge and infiltrating the sponge with a liquid lead-base bearing alloy belongs in this group, as well as iron-base bearings produced by infiltrating a porous sintered iron skeleton with the usual bearing alloys.

3. Copper-infiltrated sintered steels for high strength and corrosion resistant structural parts and copper-infiltrated iron-base diamond-metal combinations for abrasive tools.

4. Mercury-infiltrated sintered nickel and sintered iron for proximity fuses.

5. Materials having high strength and oxidation resistance at elevated temperatures on the basis of carbides and solid solutions of carbides infiltrated with high-temperature alloys.

The copper-infiltrated sintered steels have recently aroused great interest. One of the principal limitations of sintered iron and steel structural parts has been their physical properties, which are in the range of gray cast iron rather than of steel. Through infiltration with liquid copper or copper alloys these properties can be improved considerably without resorting to expensive operations such as repressing or hot pressing. *(To p. 110)*



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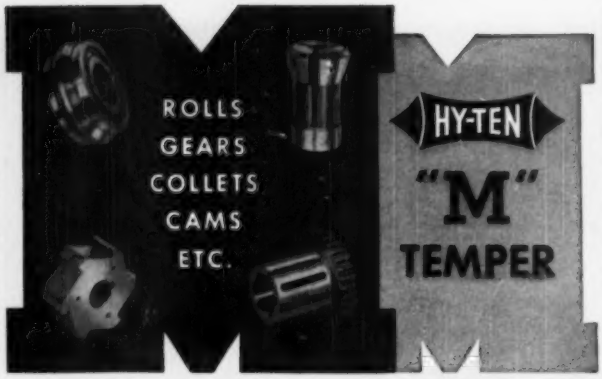


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## Infiltrated Alloys

*(Continued from p. 108)*

As an example, the properties of a sintered 0.3% carbon steel compacted from "Hametag" (eddy-mill) iron powder and sintered for 1 hr. at 2230° F. are shown in Table I as sintered, after copper infiltration with 10 to 12% Cu by volume and after infiltration and heat treatment. The data are based on experiments of the authors. [For data by American investigators, see the article on p. 64.]

**Table I — Properties of Copper-Infiltrated Iron**

| | Vickers Hardness | Tensile Strength | Elongation |
|---|---|---|---|
| A | 99 | 36,600 psi. | 5.8% |
| B | 262 | 102,000 | 7.3 |
| C | 255 | 108,600 | 13.5 |

A = as sintered for 1 hr. at 2230° F.; B = infiltrated with 10 to 12% Cu by volume; C = infiltrated, quenched from 1650° F. in water and tempered 2 hr. at 1100° F.

The technique of infiltrating a porous skeleton with liquid metal can also be applied to carbides, nitrides and borides. Sintered titanium carbide or sintered mixtures of titanium and molybdenum carbides may be infiltrated by liquid alloys having high-temperature strength and oxidation resistance such as the well-known 80-20 Ni-Cr alloy or the newer cobalt-base alloys. By this infiltration process the strength and oxidation resistance of the carbide skeleton can be increased several fold.

F. V. Lenel

## Cemented Carbides Without Metallic Binders*

ONE of the principal disadvantages of cemented carbides for high-temperature applications is the fact that they are plastic rather than rigid at their usual sintering temperatures; consequently the aim of the investigation reported was to produce cemented carbides free of binder metal, and which would

*(Continued on p. 120)*

*Abstract of "Sintering Carbides by Means of Fugitive Binders", by Laurence S. Foster. U. S. Atomic Energy Commission document AECD-2464, declassified Jan. 28, 1949. Technical Information Branch, A.E.C., Oak Ridge, Tenn.

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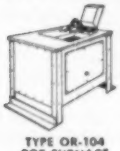

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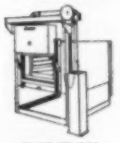

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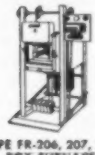

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# ENGINEERING DIGEST OF NEW PRODUCTS

**FATIGUE TESTING MACHINE:** Filling a wide gap in the capacity range of Baldwin-Sonntag Universal fatigue and simulated service testing machines, a new machine of 10,000 lb. total capacity (5000 lb. maximum static preload plus 5000 lb. maximum alternating force), known as the SF-10-U, is announced by the Baldwin Locomotive Works. This machine applies alternating vertical forces at a frequency of 18,000 cycles per minute and maximum amplitude of ⅛ in. Load accuracy is within 2% of load or 0.4% of capacity, whichever may be the greater. The machine is driven by a 2-h.p. synchronous motor.

The new fatigue machine operates by the same constant-force principle as other SF-type fatigue machines. Dynamic loads are applied by the centrifugal force of a mass rotating at constant speed in an oscillating frame. The force is accurately controlled by varying the distance between the mass and its center of rotation. Inertia forces are compensated by carefully designed springs and calibrated weights.

The new machine will accurately maintain static preloads up to 5000 lb. during tests. Preload is automatically reset to the predetermined value whenever an electrical contact is made by a slight change in the length of calibrated loading springs (induced by creep in the specimen or other cause). A relay circuit then activates a motor to drive preloading screws.

**For further information circle no. 1 on literature request card on page 116B**

**ELECTRONIC TORCH:** Hot enough to cut holes in firebrick and to melt tungsten, hardest to melt of all the elements, an "electronic torch" has been developed by scientists of the General Electric Company's Research Laboratory.

By combining high-frequency radio signals and various gases, temperatures considerably higher than the melting point of tungsten (3370° C.) can be produced. The electronic torch is still in the laboratory stage, and its commercial possibilities have yet to be more fully explored.

Heart of the torch is an electron tube known as a "magnetron", which produces radio waves with the extremely high frequency of one billion cycles per second. Leading from the tube is an antenna made of two short metal cylinders, one within the other. A high-frequency arc can be made to form on the end of the antenna. If certain gases, among them nitrogen and carbon dioxide, are fed past the arc, the electronic torch results, resembling a jet of flame about nine inches long.

The high temperatures produced on any surface placed in the jet are caused almost entirely by the heat generated as atoms join together to form molecules. The molecules of the gases are broken up into atoms by the high-frequency arc. These atoms join together again on surfaces placed in the torch. The jet itself is not necessarily hot.

**For further information circle no. 2 on literature request card on page 116B**

**PELLET TEMPERATURE INDICATORS:** The development of high temperature ratings of Tempil® Pellets to indicate 2100, 2200, 2300, 2400 and 2500° F. is announced by the Tempil® Corporation.

Beginning with 113° F., Tempil® Pellets are now available in 12½-degree steps to 400° F., and in 100-degree steps from 2000 to 2500° F.

Tempilstiks®, the crayon form of temperature indicator, are available in corresponding intervals from 113 to 2000° F.; while Tempilaq®, the paint form of temperature indicator, is available in similar steps from 113 to 1600° F. only.

**For further information circle no. 3 on literature request card on page 116B**

**HIGH VACUUM GAGE:** A new McLeod-type high vacuum gage, with a working range of 0.05 to 50 mm. is announced by the F. J. Stokes Machine Company. Calibrated in millimeters, the lowest scale division is 0.01 mm. (10 microns).

The wide range of this new vacuum gage fills the gap between present low-range vacuum gages and dial-type measuring instruments. It gives accurate readings in the "twilight zone" not accurately covered previously. The gage performs excellently in applications subject to excessive contamination during operation.

The new high vacuum gage is easily and quickly operated for rapid readings.

The lightweight portable gage weighs 6½ lbs., with over-all dimensions of 7½ x 11⅞ x 4½ in. Gage is housed in modern plastic case and is furnished complete with one pound of mercury.

**For further information circle no. 4 on literature request card on page 116B**

**CHROMIUM PLATING SOLUTION:** A new self-regulating high speed chromium plating solution has been developed by United Chromium, Inc. According to the company, all tests indicate that the new solution is the greatest advance in the art of chromium plating in more than twenty years. The new Unichrom SRHS Chromium Plating solution differs in several very important respects from the conventional solution which has been in use since 1924. It is self-regulating. It has higher cathode efficiency. It has better covering power. It has a wider bright plate range. It is less sensitive to interruptions in current. When plated over nickel, it has less tendency to produce "rainbow plate" at the line where the chromium stops.

**For further information circle no. 5 on literature request card on page 116B**

**COPPER PASTE:** Copper in paste form, providing substantial savings in the assembly of parts for furnace copper brazing, has been developed by the Metals Refining Company, a division of the Glidden Company.

Called "Cubond", the paste provides a source of copper that can be applied with more speed and less waste than conventional sources such as rings, foil, slugs and electroplate.

At the same time, the company developed applicator guns which apply Cubond as an extrusion in the form of rounds or ribbons in definite quantity, depending on the trigger setting. These guns are for pneumatic or hand use. The pneumatic type can be set for automatic operation and actuated by foot pedals, cams or electrical controls.

The pastes are produced in two general types: one with a synthetic petroleum base and the other containing a base that does not change viscosity with changes in temperature.

Consistency of the petroleum-base pastes is sufficiently fluid to permit extrusion from guns without thinning. However, it may be thinned for application by brush, spray or dip. The vehicle thins slightly with temperature rise, making this paste ideal for operations where it is expedient to apply the copper in one spot and depend on vehicle fluidity to carry the copper to nearby areas.

The petroleum-base products will not settle, harden or dry, either in the can or on the job. They contain minute quantities of practically residue-free non-corrosive flux. There is no chemical reaction between the copper source and the vehicle and a bright, clean part surface results from the use of the pastes. They have good adherence to steel and supply copper in a fluidity equal to that of wire at brazing temperatures. Thinning with kerosene or light fuel oil to paint consistency is possible without settling.

Since the non-petroleum-base pastes do not thin with temperature rises, there is less tendency for the material to flow away from the joint. In addition, when the vehicle decomposes in the furnace, the products are hydrogen and carbon monoxide, the same as those used for most furnace atmospheres. These pastes are of heavy consistency and are used only in special cases without thinning. They may be thinned either with water or permanent-type antifreeze.

By incorporation of a small amount of finely divided iron powder, a cementing material can be made from copper and used in many cases where loose fits for expansion purposes are required. The cement action holds the copper in place, fills cracks or loose joints and provides fillets to the desired size.

**For further information circle no. 6 on literature request card on page 116B**

**NEW "STRAIGHT-LINE" INPUT CONTROL UNIT:** A new "straight-line" temperature control unit has just been offered by the Claud S. Gordon Company. Known as their Xactline it is used with any standard type or make of pyrometer controller for unusually close temperature variation control in the plastic, molding, tempering, aluminum heat-treating and other precision heat-processing fields. The manufacturer claims the extreme sensitivity of this unit has kept temperature variations as low as ½ degree F. plus or minus and power on-off cycles as short as three seconds.

This Xactline is fully automatic and unusually simple in that it is not dependent upon any mechanical coordination with other equipment. It is readily applicable to all types of electric furnaces, ovens, injection molding machines, etc., employing conventional millivoltmeter and potentiometer-type controlling pyrometers or gas fired equipment employing solenoid-controlled or motor-operated valves. The unit, ready to connect, is enclosed in a black wrinkle finish metal case, 8½ in. high x 6¼ in. wide and 3 in. deep. The case design permits wall mounting or flush mounting in cabinets or panels.

**For further information circle no. 7 on literature request card on page 116B**


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| 163 | 313 | 600 | 1150 | 1700 |
| 175 | 325 | 650 | 1200 | 1750 |
| 188 | 338 | 700 | 1250 | 1800 |
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# *ENGINEERING DIGEST OF NEW PRODUCTS*

**MAGNIFYING MICROMETER:** New Magnifying Micrometer used for thickness measurements of plating, paint and enamels is announced by Krouse Testing Machine Company.

This instrument is used to compare magnetic force measurements between a coating of unknown thickness and the tapered precision coating gage of similar base and coating magnetic characteristics. It may be used on sloping, overhead or curved surfaces, by holding the gage so the Magnifying Micrometer is inclined at the same angle as used in test, eliminating gravity effects.

**For further information circle no. 8 on literature request card on page 116B**

**PREFORMED SOLDER:** Solder, preformed in rings, pellets, washers, unusual shapes and sizes to specifications, is available through the Kester Solder Company. Uniform results are assured where continuous or repetitious soldering is required. By supplying the same amount of solder and flux on every unit soldered, waste is eliminated and rejects are reduced to a minimum.

**For further information circle no. 9 on literature request card on page 116B**

**PORTABLE METAL MELTING FURNACE:** A low cost portable electric furnace that melts up to 600 pennyweight gold, 1½ lbs. of brass or 8 ozs. aluminum is announced by The Jelrus Company, Inc.

This lightweight (6¾ lbs.) unit is 10 in. high and 8 in. wide. It operates on 110 volt a.c. or d.c. current in a temperature range up to 2000° F. The "Handy-Melt" furnace is equipped with a pyrometer that serves to indicate metal temperatures, thereby assuring the user of consistent results in successive melts. A graphite crucible provides a beneficial reducing atmosphere and eliminates undesirable oxidation of metal during melting.

When ready to pour the liquid metal, the entire furnace is hand lifted by means of an insulated handle and the contents emptied into any receiving medium. Price is $82.00.

**For further information circle no. 10 on literature request card on page 116B**

**LOW-CARBON STAINLESS STEELS MINIMIZE INTERGRANULAR CORROSION:** Carnegie-Illinois Steel Corporation announces that it is prepared for commercial production of low-carbon (0.03% max.) stainless steels.

Up to the present it has been necessary to add columbium or titanium to austenitic stainless steels as "stabilizers" to minimize the adverse effects of carbon and thereby render the alloy less susceptible to intergranular corrosion.

It has taken a decade to prove that the manufacturing techniques are economically sound and to accumulate sufficient corrosion-testing data to justify consumer acceptance of 0.03% maximum carbon stainless steels for use in many applications in which columbium or titanium stabilized stainless steels were formerly used. Moreover, the testing program has indicated that, on the basis of established standards, the 18-8 steels containing not more than 0.03% carbon have a resistance to intergranular corrosion equivalent to that of 18-8 columbium and titanium stainless steels.

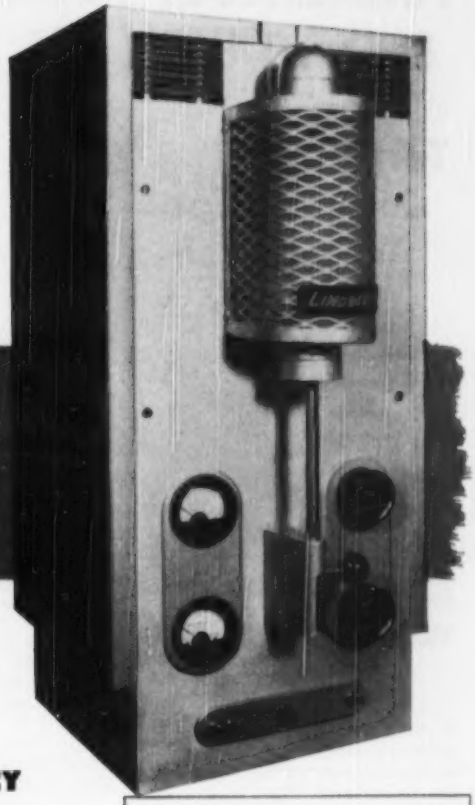
Welding tests have confirmed these results and demonstrated that the low-carbon 18-8 materials can replace the stabilized types for those applications, such as welding, that involve short heating times in the sensitizing temperature range.

**For further information circle no. 11 on literature request card on page 116B**

# NOW...

## CARBON ANALYSIS

## in a FLASH



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**NEW STANDARDS OF ACCURACY**

- Ready in the morning in 57 seconds. Instantly from then on.
- 90% less power consumption.
- No limit on temperatures.
- Glass combustion tube provides visibility of operation.
- Combustion tubes at half the cost, last many times longer.
- Shorter tube advantageous for volumetric method.
- No elements to burn out.
- Heats nothing but the sample.
- Eliminates excess heat from laboratory.

*For further details ask for Bulletin 910.*

**VOLUMETRIC**
**GRAVIMETRIC**

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| Carbon | Steel |
| Sulphur | Cast Iron |
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**Lindberg Engineering Company • 2448 West Hubbard Street • Chicago 12, Illinois**

# AMAZINGLY EASY TO USE for Tensile, Compression, Transverse Tests

## Model MP-10 UNIVERSAL TESTING MACHINE

A compact, motorized, hydraulically operated machine furnished in capacities up to 100,000 pounds. So constructed that "true axial pull" is imposed on the specimen without any side loads. This is accomplished by placing the hydraulic cylinder at the top of the machine rather than in the base—an exclusive STEEL CITY feature. Comes complete with pulling jaws, compression plates, two easy-to-read maximum indicating gauges and wiring to customer's specifications. Write for descriptive bulletin.

**SEND US YOUR TESTING PROBLEM**

We can supply or develop the machine you need. Full line of Brinell hardness, ductility, tensile, transverse, compression, and hydrostatic machines. Send us details of problems.

Steel City Testing Machines Inc.

8835 Livernois • Detroit 4, Mich.




**SUPERALLOYS:** Metals—which are harder, stronger, and more heat-resistant than the finest grades of steel—are now being used to manufacture parts of unprecedented durability for revolutionary new-type jet-propulsion airplanes, guided missiles, and rockets at Stainless Steel Products, Inc.

Superalloys comprise various quantities of rare-earth metals which have not been previously used as commercial metallic materials, and can be fabricated as parts that will withstand the extreme stresses and high operating temperatures encountered during flights at speeds of more than 1000 miles per hour.

The superalloys, developed for military usage, are now being made available to a limited extent for non-military production.

Because of their extreme toughness, the new metals have necessitated the development of a new forming process whereby they are preheated to temperatures exceeding 2000° F. so that they will become ductile enough to be shaped with hammer-like machine tools. After they are formed and finally hardened by means of a special heat treatment, superalloy parts can withstand operating temperatures of more than 1500° F.—enough to ruin first-quality steels—and in some cases superalloys will actually gain strength during prolonged high-temperature exposures.

Superalloys have extreme corrosion resistance, like stainless steels. However, they have about twice as much mechanical strength as stainless steels and are scarcely scratched by blows which could shatter conventional metals.

**For further information circle no. 12 on literature request card on page 116B**

**TANK IMMERSION HEATER:** A new portable tank immersion heater for heating oil and water solutions, tar, paraffin, glue, solvent cleaners, and other similar compounds has just been announced by the Edwin L. Wiegand Company, manufacturers of Chromalox electric heating units.

These heaters are rated from 2 to 18 kilowatts, 115 or 550 volts, single or 3-phase. Copper, steel, Inconel, or stainless steel sheath is available, depending upon the corrosive properties of the solution to be heated. The heating elements at the bottom of the vertical riser range in length from 12½ to 53 in. in straight sections. They may also be supplied in a circular shape to accommodate usage in round tanks with a minimum opening of 10½ in. The riser can be fabricated in varying lengths to suit any tank depth.

The heated section can be had with either two or three hairpin elements. Two-element heaters are designed for a uniform dissipation of heat over the length of the tank. Three-element heaters afford a high concentration of heat in confined areas.

**For further information circle no. 13 on literature request card on page 116B**

**DETECTING IMPURITIES IN METALS:** In the vacuum fusion apparatus in use at National Research Corporation, impurities in metals can be detected even when the percentage of a given element is as small as $10^{-5}$ (0.00001%) or one part in ten million.

This equipment was designed and assembled by the company's Research Division as a tool for use in analyzing for minute impurities contained in highly purified metals.

During the various stages of preparation all metals retain or pick up small quantities of oxygen, hydrogen, nitrogen and carbon. It has long been known that even minute amounts of these impurities may produce marked effects on the final properties of the metals. The above-mentioned elements may be contained as gaseous occlusions in structural faults, in solution or held in actual chemical combination as oxides, hydrides, nitrides and carbides of various composition and degree of stability. Among the properties which have been found to be markedly affected by gaseous impurities are drawing characteristics, ductility at both elevated and room temperatures, tendency toward strain embrittlement, and heat-treated properties as affected by the degree of effective utilization of reactive alloy additions. As the demand for special alloys containing reactive metals and for highly purified metals is rapidly increasing, it becomes more and more important to determine the exact relationship between the amount of an impurity and its ultimate effect on the properties of a given metal or alloy.

Ordinary analytical procedures for the determination of the elements in question are impracticable in the percentage range encountered. Hence, vacuum fusion and vacuum combustion methods were developed specifically to handle this problem.

This equipment is in continuous use at National Research Corporation in connection with its continuing development of vacuum cast metals.

**For further information circle no. 14 on literature request card on page 116B**

# WHAT'S NEW
## IN MANUFACTURERS' LITERATURE

### 15. Abrasive Wear
Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

### 16. Alloys, Briquetted
How cast iron quality can be improved through the addition of briquetted ferroalloys of silicon, manganese, and chromium is discussed in a new 24-page booklet, entitled "Briquetted Alloys for the Iron Foundry Industry". *Electro Metallurgical Co.*

### 17. Alloys, Bronze
New catalog entitled "Bronze and Copper Bearings and Castings" gives physical properties and composition specifications for 20 different bronze alloys and 5 aluminum and manganese bronzes. *American Brake Shoe Co. National Bearing Div.*

### 18. Arc Welding
Hobart Arc Welding News, a booklet published periodically, contains latest developments in the arc welding field. *Hobart Brothers Co.*

### 19. Bars, Forging
There is a stainless steel "tailored" to fit your specifications for chemical and physical properties. Write for 112-page booklet of forging data, "Evaluating the Forgeability of Steels". *Timken Roller Bearing Co.*

### 20. Brazing
Easy-Flo simple, versatile method of fabricating ferrous, nonferrous and dissimilar metals is described in bulletins 15-A and 15. *Handy & Harman.*

### 21. Carbon Analysis
Bulletin 910 describes new electronic method of carbon analysis for steel and cast iron. *Lindberg Engineering Co.*

### 22. Carburizing-Martempering
Article entitled "Carburizing-Martempering Procedure Streamlines Crankshaft Heat Treating" covers technique employed in combining liquid carburizing and martempering in a single heating operation. The economies effected are compared with the heat treating process replaced. *Ajax Electric Co.*

### 23. Castings
New booklets entitled "Engineering Properties and Applications of Ni-Hard" and "Buyers Guide for Ni-Hard Castings" list general information on selection and performance of this unique nickel-chromium white cast iron. *International Nickel Co.*

### 24. Castings
New 72-page book entitled "Castings by Norway" contains information on aluminum and rare earth magnesium alloy castings. This book also includes helpful, understandable information on the casting of aluminum, magnesium, brass, bronze and ammonia as well as numerous tables showing mechanical properties, chemical analysis and physical characteristics of these metals. *Norwalt Foundry Co.*

### 25. Castings
New 16-page booklet discusses metal specifications, chemical properties and physical properties of a series of carbon and alloy steels from normal carbon steel through various combinations of chromium, molybdenum and other types of alloy steels. *Dodge Steel Co.*

### 26. Castings, Bronze
Illustrated booklet describes precision machine work, bronze castings and forgings bronze products produced at this firm. *American Non-Ferrous Bronze Co.*

### 27. Castings, Steel
New 32-page brochure discusses 12 basic considerations which should govern the selection of a supplier of steel castings. *Continental Foundry & Machine Co.*

### 28. Coatings, Metal
Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

### 29. Combustion Control
"Combustion Control for Industry", a new fact-filled free booklet now available, shows how greater savings can be realized by proper combustion in heat treating units of any size. *Cities Service Oil Co.*

### 30. Combustion Tubes
Electric combustion tubes recommended for all types of work requiring gas-tight tubes for temperatures up to 1900° F. Described in bulletin 214. *Harrell Corp.*

### 31. Control Equipment
12-page folder deals with two different, complete high-temperature cooling laboratories for determining the physical properties of molding materials. Also contains technical data and high temperature properties of molding materials. *Harry W. Dietert Co.*

### 32. Controls, Electronic
62-page book lists 45 case studies on cutting production costs with electronic controls. *Photoswitch, Inc.*

### 33. Copper Sheets
New 23-page booklet, the product of a ten-year program of design development and test combined with field investigations, contains complete, detailed specifications for all types of sheet metal installations employing copper. *Revere Copper & Brass, Inc.*

### 34. Corrosion
Complete line of quality rust preventives, both oil and petroleum types for interior and exterior use, described in booklet "Gulf Rust Preventives". *Gulf Oil Corp.*

### 35. Cut-Off Machines
New bulletin describes advantages in performance of new AB cut-off machines in metallurgical laboratory. *Buehler, Ltd.*

### 36. Cutting Fluid
Report 149 gives actual performance of Lenol cutting fluids based on description by a valve manufacturer. In a test run of 431 forged steel valve bonnets, Lenol increased tapping speeds 113%, and life of taps 549 to 610%. *P. R. Anderson Oil Co.*

### 37. Descaling
Booklet entitled "Sprout Sutton Hyatron Descaling Process" discusses the process, how it works and where it is used, along with interesting photographic diagrams and technical information. Designed to help you "Let Sprout Do the Work" on your scale removal jobs. *The Sprout-Waldron & Co.*

### 38. Die Blocks
24-page booklet on "Finkl Quenched and Tempered Die Blocks" tells about four types of Finkl die block steel, how to select the right one for your job, how to make your dies last longer, and many other interesting and helpful facts. *A. Finkl & Sons Co.*

### 39. Die Castings
Revealing book, "How Magnesium Pays", gives case studies of the economical use of magnesium in a wide range of products. *Dow Chemical Co.*

### 40. Electrodes
4-page bulletin lists applications and advantages of "Chrome-Norole Weld-Arc" electrodes for hard surfacing. *Alloy Rods Co.*

### 41. Electrodes
Write for new jackscrew electrode catalog GEC-482 with latest coil construction of an electrode to suit every application. *General Electric Co.*

### 42. Fasteners
Manufacturers, who perform partial or complete assembling operations, will find important business information in this new 28-page illustrated "Stud" catalog. *Pheoll Mfg. Co.*

### 43. Fastening Specialties
New 16-page catalog features full descriptive and engineering data on the broad range of Shakeproof thread inserts, machine screws, panel fasteners, spring retaining washers, etc., and various newly-developed items. *South Chester Corp.*

### 44. Films and Plates
Special sensitized plates and films for the scientific and industrial laboratories are described in a new 8-page book of specifications issued by the Eastman Kodak Co. *Eastman Kodak Co.*

### 45. Finishes
Bulletin 1400 tells how the new "Hydro-Finish" provides cleaner, smoother surfaces prior to coating processes; gives hours on the production line. *Pangborn Corp.*

### 46. Forgings
New catalog 51 contains 56 pages covering such topics as type of forgings, steel and how to specify forgings, tolerances, dimensions, stresses and related data, design aid dates and symbol sheet, types, etc. Well illustrated with tables, drawings and photographs. *Merrill Brothers Co.*

### 47. Furnaces
New 32-page fully illustrated catalog on Vaporarc-Hearth atmosphere furnaces for the treatment of engineering components and various approved metals by use of fluid pump assembly. *Leeds & Northrup Co.*

### 48. Furnaces
Bulletins H-23 and H-24 discuss the problem of temperature control in metal melting furnaces. *Edison Prod. & Engineering Co.*

### 49. Furnaces
Bulletin 815-AB gives details for increased production economy with reciprocating furnaces. *American Gas Furnace Co.*

### 50. Furnaces
72-page bulletin 116 describes electric salt bath furnaces and their many uses in hardening, annealing, brazing, tempering, quenching, etc. *Ajax Electrothermic Corp.*

### 51. Furnaces, Combustion Tube
For full information on combustion tube furnaces with exclusive features of multiple heating units readily replaceable, write today for bulletin 1258. *Hoe Duty Electric Co.*

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# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

### 52. Gas-Cutting Guide

Pocket-sized oxyacetylene machine gas-cutting guide has now been reprinted. By means of a handy slide-rule type of chart, tip numbers are indicated, and oxygen and acetylene pressures, speed in inches per minute, gas consumption and approximate width of kerf are all easily read down one column. Cleaning drill sizes are also indicated. *Air Reduction Sales Co.*

### 53. Graphite Combustion Chambers

M-5002 describes the graphite combustion chambers and "Karlsite" impervious graphite burner nozzles. Outlines operation of the complete system and points out the principal features, such as long life, absence of corrosion, minimum maintenance, ability to withstand thermal shock, simplicity and moderate installed first cost. *National Carbon Co.*

### 54. Grinding and Polishing

6-page pamphlet gives facts about backstand belt grinding and polishing. *Arnsco & Co.*

### 55. Grinding Jig

New 4-page brochure entitled "Kennametal Machine Bit Grinding Jig" describes and illustrates grinding of bits for mining machinery. *Kennametal, Inc.*

### 56. Induction Heating

Learn the many advantages of applying Tocco induction heating for hardening, brazing, soldering, annealing or forging operations. Send for free booklet now available. *Ohio Crankshaft Co.*

### 57. Laboratory Technique

Booklet published periodically offered to those interested in keeping informed on the latest developments of laboratory apparatus and techniques. *Fisher Scientific Co.*

### 58. Lubrication of Hot Metals

New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal forming operations. *Acheson Colloids Corp.*

### 59. Machine Design

Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

### 60. Metal Cleaner

Novel 4-page file-size folder on Diversey 909, heavy-duty soak tank metal cleaner discusses applications and directions for its use. *Diversey Corp.*

### 61. Metal Treating

16-page ready-to-file data folder gives technical information on metal treating and finishing products. *Heatbath Corp.*

### 62. Microcastings

This 16-page booklet describes many applications for microcastings and also explains the process itself. *Microcast Div., Austenal Laboratories.*

### 63. Nonferrous Cleaners

New bulletin describing the use of alkaline cleaner for degreasing of nonferrous metals, including copper, brass, tin alloys and lead alloys. *Enthone, Inc.*

### 64. Oil Burner

New 24-page catalog 810 describes the Hauck proportioning oil burner. A precision instrument for better combustion, more accurate control of furnace temperature and atmosphere. *Hauck Mfg. Co.*

### 65. Oil, Quenching

Catalog 9-4146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett.*

### 66. Optical Glass

New bulletin E-30 discusses the physical and chemical properties of optical glass. This book also contains general data on optical glass products. *Bausch & Lomb Optical Co.*

### 67. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co.*

### 68. Polishing Machinery

Catalog 60 illustrates complete line of polishing, buffing, grinding and deburring machinery. *Hammond Machinery Builders, Inc.*

### 69. Powder Metallurgy

New 36-page booklet entitled "Powder Metallurgy Today" discusses the processes, applications, characteristics and design of powder metal parts in modern industry. *F. J. Stokes Machine Co.*

### 70. Powder Metals

Technical Bulletin 367, "Metal Powders and Some of Their Applications", illustrates and describes some of the more important applications for iron, steel, nickel, manganese and silicon powders. *National Kadiner Co.*

### 71. "Precisionomics"

A new house organ issued every other month will feature articles directed to the scientific and laboratory worker engaged in the petroleum and metallurgical fields. *Precision Scientific Co.*

### 72. Products and Services

66-page illustrated book describes the products and services offered to industry and outlines the divisional structure through which such products are sold. *American Cyanamid Co.*

### 73. Pyrometer

Catalog Section 25 illustrates and describes new multiple point pyrometer indicator which provides a rapid means for measuring temperatures from one to six thermocouple locations. *Thermo Electric Co.*

### 74. Roslynn Metal

Pamphlet entitled "Roslyn Metal for Heat Resisting Applications" describes this useful clad-metal with outer surfaces of stainless steel bonded to an inner layer of high-conductivity copper. *American Cladmetal Co.*

### 75. Rotary Files and Burs

Brochure illustrating complete line of rotary files and burs for removing scales from castings; cutting in hard-to-get-at places; die-sinking; pattern making, etc. Also includes sizes and prices. *Martindale Electric Co.*

### 76. Salt Baths

32-page bulletin entitled "Houghton Liquid Salt Baths" discusses the advantages of this process for tempering, brazing, annealing, hardening, reheating, and carburizing. Also contains many pages of factual heat treating data. *E. F. Houghton & Co.*

### 77. Steel, Alloy

New 32-page brochure "The Transportation Steel", describing Otiscoloy, low alloy high strength steel. Complete technical data including physical properties of Otiscoloy is enlivened with stories and excellent illustrations of fabricating operations and finished products. *Jones & Laughlin Steel Corp.*

### 78. Steel, Alloy

New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc.*

### 79. Steel, Alloy

New bulletin describes Evanstel, a chrome-nickel molybdenum alloy designed for hard service. *Chicago Steel Foundry Co.*

### 80. Steels, Alloy

Critical points of 85 standard carbon and alloy steels, legibly printed on a heating celluloid pocket card 2¾ x 4¾. Includes Ac1, Ac3, Ar1, Ar3 and Ms temperatures for A.I.S.I. and S.A.E. types in current use. *Republic Steel Corp.*

### 81. Strain Gages

Bulletin 279B gives detailed procedures for attaching SR-4 resistant wire strain gages to surfaces and is illustrated by 18 cartoons, animating the gages to show their reactions to correct and incorrect methods. *Baldwin Locomotive Works.*

### 82. Surface Cleaner

New folder describes the Oakite CrysCoat process for preparing metal surfaces for painting. *Oakite Products, Inc.*

### 83. Tank, Heating and Cooling

New 6-page bulletin makes a direct comparison between plate coil and pipe coil methods of heat exchange for tank heating and cooling. *Kold-Hold Mfg. Co.*

### 84. Testing

Bulletin 61 describes new universal testing machine for low cost industrial production and quality control, laboratory, educational, and shop testing of metals. *Tinius Olsen Testing Machine Co.*

### 85. Tools, Carbide

New supplement lists prices and specifications on all standard carboloy tools, blanks and diamond products. *Carboloy Co., Inc.*

### 86. Weld Coatings

12-page pamphlet includes abrasion charts for a large number of weld coating materials. Factors covered include various types of abrasion, crush service, dies, valves, etc. *Texas Alloy Products Co.*

### 87. Welding Bronze

How to save material by bronze welding, and ideal combination for repair welding, building up worn surfaces and production welding, described in new 17th edition of B-13. *American Brass Co.*

### 88. Zinc, Coatings

16-page illustrated booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. *St. Joseph Lead Co.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

January, 1950

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Students should write direct to manufacturers.

# ELIMINATE STOOL STICKERS

## with "NATIONAL" Graphite Stool Inserts!

✻ **Here are the conclusions drawn from five years of testing "National" graphite stool inserts:**

**1.** Cast-in graphite stool inserts eliminate stool stickers.

**2.** Cast-in graphite inserts, of proper grade and size, produce a stool which will outlast an ordinary all-iron stool by as much as 86%.

**3.** Cast-in graphite inserts do not adversely affect the quality of the steel ingot.

### ADVANTAGES ARE:

**Track time for ingot trains held to a minimum. Maintenance cost of stripper cranes materially reduced. Time and labor saved all along the line.**

✻ Write for free reprint of "Graphite Stool Inserts for Big-end-down Molds" from the September, 1949, issue of *Iron and Steel Engineer*. Address Dept. MP.

***Use Carbon Mold Plugs for Plug-bottom Molds!***

No contamination of ingot. • May be used more than once; no stickers. • Light, strong, easy to handle. • Consistently accurate in dimension. • Resist thermal shock and hot-metal erosion.

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*Division Sales Offices:* Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

**Foreign Department: New York, U.S.A.**

*These products sold in Canada by Canadian National Carbon Company, Ltd., Toronto 4.*

# Now Available . . .

***to producers and fabricators of***
***Zinc-Coated Iron & Steel Products***

***"St. Joe Electro-Thermic Zinc and Galvanizing"*** **is a 16-page, 8½ x 11" illustrated booklet which has just been published by the St. Joseph Lead Company. The booklet discusses the origin of galvanizing, the various zinc coating methods employed today and the advantages of zinc as a protective coating for iron and steel products. The importance of this application of zinc can readily be gauged by the fact that the galvanizing of iron and steel products has for many years accounted for the metal's largest single use. In 1948, for example, nearly 50% of the metallic zinc consumed in the United States was used for this purpose.**

***Copies are available to companies interested in galvanizing***

## ST. JOSEPH LEAD COMPANY

250 PARK AVENUE • ELdorado 5-3200 • NEW YORK 17, N. Y.

# *Small Castings* that do BIG JOBS

Forward-looking design engineers find that Microcast, for small components, offers many opportunities for product improvement and substantial savings in cost. This is particularly true where resistance to wear or corrosion is desired or where the part is of intricate shape, requiring expensive machining operations under conventional production methods.

With the Microcast Process, the unusual properties of the extremely hard, high-melting-point alloys can be used to full advantage. Small components of intricate shape, as cast, are dimensionally uniform, of sound structure, and to such close tolerances that little or no machining is required.

**SPECIALISTS IN POWER BLADING**

The "guts" of any turbine-type power development unit is its power blading. The Microcast Process has produced millions of these blades, utilizing the high-melting-point, non-machineable alloys at substantially lower costs than other methods of manufacture.

**TIME FOR REFRESHMENT**

When you step up to your favorite fountain chances are the syrup for your soda, pumps through a Microcast dispensing part. What's important is that these 18-8 stainless steel Microcastings resulted in considerable savings in die and machining costs over previous production methods.

**IT AIN'T HAY**

At least the operation is not complete until the modern hay baler goes into action! A Microcast gear on the knotter twine disc assembly eliminates the costly milling and hobbing operations ordinarily required to form teeth.

## *Microcastings*...IN A WIDE VARIETY OF PRODUCTS

## AFFORD BETTER PERFORMANCE AT LOWER COST

**Write for New Microcasting Booklet**

MICROCAST PRECISION CASTINGS PROCESS

MICROCAST

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More complete information on Microcast is contained in a new 16-page booklet published by Austenal Laboratories, Inc., originators of the Microcast Process. The booklet describes many applications for Microcasting and also explains the process itself. Write for your copy today.

*The name MICROCAST is a registered trademark of Austenal Laboratories, Inc.*

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**THE DELAWARE CONTROLLED ATMOSPHERE FURNACE**

features a unique tangential firing principle. This method of heating assures:

1. Maximum uniformity of temperature in all parts of the muffle.
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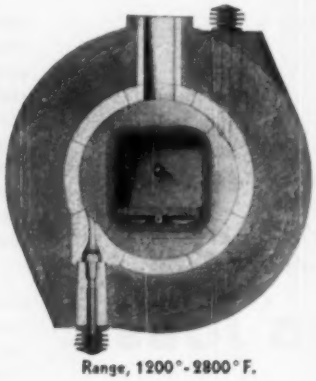

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## Cemented Carbides

*(Starts on p. 110)*

be rigid up to very high temperatures. For this purpose mixtures of refractory carbides with very small quantities of metallic binders (on the order of ¼ to ½%) were sintered in a vacuum at temperatures much higher than usually employed, during which substantially all the binder metal sublimed and a binder-free cemented carbide remained. Besides its practical importance, the investigation provided a partial answer to the controversial question as to whether the high strength of cemented carbides is due to the presence of the thin film of metal cement or to the formation of a refractory carbide skeleton with high inherent strength.

Tungsten carbide, tantalum carbide and columbium carbide were investigated. The commercial carbides, as received, were milled in a mill lined with cemented carbide blocks and with carbide balls for grinders, for periods of 100 to 200 hr. Determinations by photelometer showed that the average particle size was substantially reduced. The metallic binder — either in the form of metal powder or as oxide — was added during this milling. Production of green compacts was facilitated by the addition of "Carbowax-4000" as a pressing lubricant; this was later removed by slowly heating the compacts to 570° F. Final sintering was by high-frequency induction in a vacuum of about 100 microns of mercury to temperatures between 3400 and 4200° F. as measured by an optical pyrometer. Chemical analysis, density, shrinkage, intercommunicating porosity, and microscopic appearance were noted.

Tungsten carbide was sintered with and without binder. Carbides sintered without a binder had relative densities of less than 90% and a considerable degree of intercommunicating porosity. On the other hand, carbides to which 0.25% nickel as metal had been added had relative densities of the order of 95% and no intercommunicating porosity — despite the fact that after sintering no remaining binder metal could be detected chemically. The results can be interpreted on the assumption that sintering is accomplished by interaction between the binder and the carbide during the heating-up part of the sintering cycle and continues

*(Continued on p. 122)*

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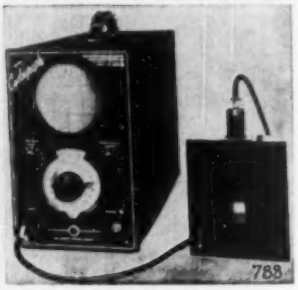

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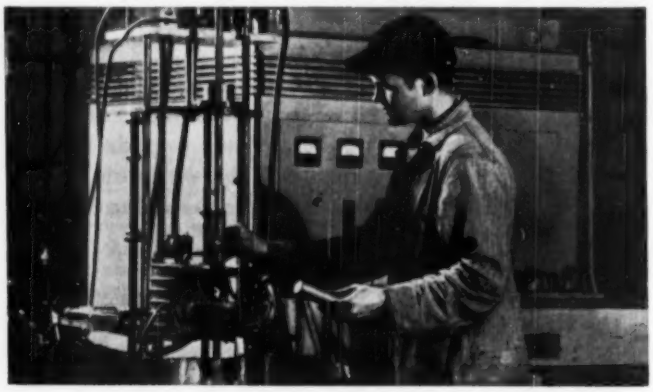

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## Cemented Carbides

*(Starts on p. 110)*

during the time when the dissolved carbides crystallize from the solution phase which eventually disappears by sublimation. This mechanism is confirmed by the eventual microstructure which consists of large prismatic tungsten carbide grains. Sintering of ball-milled tantalum carbide and columbium carbide, each mixed with 0.25% nickel, gave similar relative densities, while the microstructures consisted of large equi-axed grains of the carbides.

The tensile strength of one sample of unbonded tungsten carbide made with 0.25% cobalt as a fugitive binder was compared with that of the commercial "Carboloy No. 999" containing 3% of cobalt. Bridgman's method was used, in which the tensile strength is measured under a superimposed high hydrostatic pressure. The binder-free carbide had a strength within 15% of the carbide cemented with cobalt, which lends support to the viewpoint that the tungsten carbide skeleton makes an important contribution to the strength of cemented carbides of low cobalt content.

F. V. LENEL

## Indentation Hardness Testing*

HARDNESS TESTING has long been accepted as essential for the control of operations in the metal processing industries; yet, surprisingly enough, this book is the first to treat hardness entirely from the testing standpoint. The well-known texts on hardness by O'Neill and by Williams discuss the testing aspects, but only as part of a comprehensive inquiry into the physical and metallurgical nature of hardness.

Lysaght, on the other hand, has limited himself to hardness testing. The only theory presented is that needed for the proper understanding of testing methods and their limitations, and the mathematics is kept to the necessary minimum. Thus, this concise, well-written book should appeal strongly to

*(Continued on p. 124)*

*A review of "Indentation Hardness Testing", by Vincent E. Lysaght. Reinhold Publishing Corp., New York, 1949. 288 p. ($5.50)

On this, General Alloys' 32nd year and the writer's 50th Christmas, it is appropriate to acknowledge our great debt to Men of Metals, you Readers of METAL PROGRESS and Doers in A.S.M., who have made this business possible. Beyond the bread, you have given us the wine, and zest of life, which man derives from fine loyalties and firm friendships grown from teamwork in Peace and War. Having neglected sales effort for the past three years to render a greater service through Navy-sponsored Research and Development, it is gratifying to know we are not forgotten. For the kind words of Friendship, of Greeting and of Encouragement that you have sent this Christmastide, we are deeply grateful. We shall strive to our utmost to merit your confidence and higher expectancies from General Alloys.

# . . Rhyminiscent . .

*As I pause from press of business to pen this idle rhyme,*
*I'm taking inventory, for it's inventory time.*
*But it's not the stock I'm checking, nor dollars lost or won,*
*That concern me in accounting when final statement's done.*
*I am thinking of the "life" I've spent, the things I've done and said,*
*The things I cannot figure in the black or in the red.*
*I am thinking of the men I've met in plants throughout the land,*
*Who've given of their time to me, held out a friendly hand.*
*Who placed a certain confidence in statements that I made,*
*And staked their judgment on my claims and on the game I played.*
*I am thinking of the fellows who have gone out of their way*
*To help me put my stuff across . . . they do it every day.*
*I see friendships that are ripening, that have stood the test of years,*
*Have I kept faith with those who trusted, or am I in arrears?*
*What are dollars, few or many, to record commercial strife*
*When checked against the finer things along the path of life?*
*In intercourse with fellowmen, the give and take of trade,*
*The profit of enduring worth is not the dollar made.*
*I am humble as I contemplate how little I can say or do*
*To show that I appreciate what Men . . . one may be you . . .*
*Have done to aid me on my way.*

H. H. Harris

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## Hardness Testing

*(Continued from p. 122)*

engineers, metallurgists and others responsible for hardness testing, who want to understand this subject from the practical standpoint but are not concerned with the more abstruse aspects of hardness.

The first half of the book is devoted primarily to explanations of various indentation hardness testers used in the United States. In keeping with the title of the book, scratch hardness methods are mentioned only briefly because they are not generally suitable for testing. The space devoted to the various types of indentation hardness testers seems to be in proportion to their relative frequency of use in this country. The advantages and limitations of each type of tester are discussed thoroughly and enough history is given to show how the limitations led to the development of new types of testing instruments.

Recommended practices and the reasons for them are stated clearly. The importance of properly preparing the test surface for each type of test and of properly supporting the test specimen are emphasized frequently. The accuracy attainable with the various equipments is discussed in considerable detail.

A separate chapter is devoted to Meyer's analysis of ball penetration data, by which the degree of work hardening resulting from indentation can be determined. A similar analysis of Rockwell data is presented in the chapter on the Rockwell tester. However, those who are not already acquainted with this phase of hardness testing will probably feel that its treatment is somewhat too condensed. It might have been better to devote more space to this subject in order to discuss experimental data more fully.

The remaining half of the book is concerned with a number of separate topics. The chapters on hardness conversion and on the applicability of hardness tests should be valuable to everyone responsible for hardness testing. In both of these chapters the importance of the nature of the material being tested is emphasized. Chapters on the testing of sheet metal and of cylindrical surfaces are of more specialized interest.

The chapter on microhardness

*(Continued on p. 126)*


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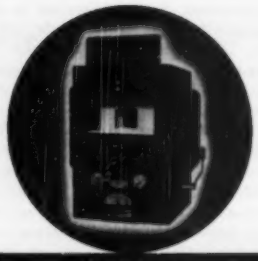

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## Hardness Testing

*(Continued from p. 124)*

testing, which is well illustrated, gives the reader a good idea of what can be accomplished in a practical way by the use of this technique. The limitations of this form of testing are discussed clearly. Although it is brought out that there may be an appreciable elastic recovery of the long diagonal of a Knoop indentation, this point was unfortunately ignored in the definition of the Knoop hardness number, where it is erroneously stated (as it always has been in the past) that this number is equal to the applied load divided by the *unrecovered* projected area of the indentation. In actual practice, the Knoop hardness is obtained from a measurement of the elastically recovered length, which is related in a simple manner to the *recovered* area.

The last chapter is devoted to the indentation hardness testing of nonmetallics, ranging from plastics to diamond. Special methods of utilizing the Rockwell tester for measurements on soft plastics are described in detail.

As is likely to happen in a first edition, there are a few typographic errors. The only one that may lead to difficulty is in the fourth line from the bottom of p. 205, where "etching in nital" should be substituted for "etching in metal".

Although the book is intended to be elementary, the author always points out clearly the numerous questions relating to hardness testing for which answers are still to be found. Those who wish to learn more about the subject will find the selected references at the end of many of the chapters an excellent guide to the literature, especially to the technical articles published in the last decade.

L. P. TARASOV

## Abrasive Wear*

THE AUTHORS present several schematic representations of the factors influencing *(To p. 128)*

*Abstracted from "Abrasive Wear of Steel, Theory and Practice", by Richard Walzel, *Berg- und Hüttenmännische Monatshefte*, Vol. 93, 1948, p. 28-33; and "Abrasive Wear of Steel Test Specimens That Can Deflect Elastically", by Richard Walzel and Richard Werner, *Berg- und Hüttenmännische Monatshefte*, Vol. 93, 1948, p. 59-62.

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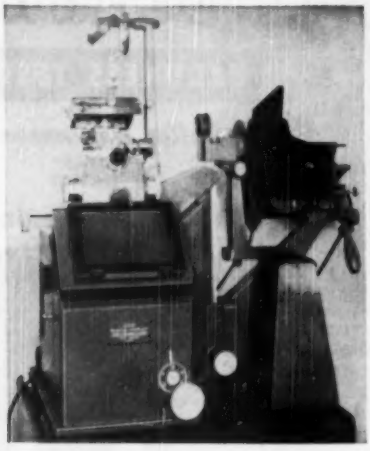

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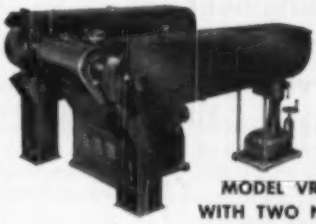

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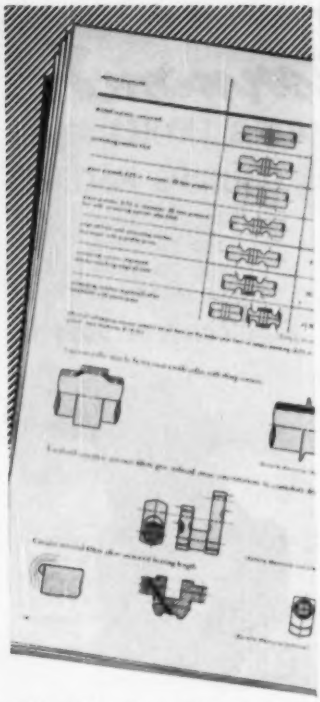

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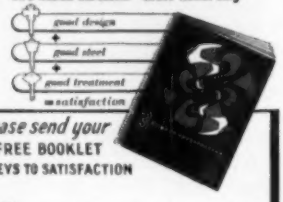


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## Abrasive Wear

*(Cont. from p. 126)* resistance to abrasive wear. Two of these are rather general; a third relates to the wear of railroad rails and lists 31 different variables in the roadbed, trackage, vehicle and operation that affect the wear of rails in service.

One variable mentioned is the presence or absence of water in tunnels; rails are worn out faster when water is present. With this problem in mind, both copper-bearing and copper-free rails were laid in an Austrian tunnel eleven years ago. Subsequent results have shown that an addition of 0.25% Cu in as-rolled pearlitic manganese steel decreased the abrasive wear by 33%.

Sometimes, but not always, greater stiffness of the material leads to greater abrasive wear. Walzel and Werner studied the abrasive wear of flat rolled steel specimens that could deflect elastically during abrasion. Abrasive wear was produced on the flat pieces in the laboratory by a reciprocating cylinder of hardened high speed steel. Both stiff and flexible specimens were studied. The absolute abrasive wear was less for a thin (flexible) specimen than for a thicker (more rigid) one under the same conditions. These results have no direct application to the service deterioration of rails because a smaller rail profile and a less rigid foundation would not stand the demands of modern railway service.

OTTO MEET

## Aluminum Coating

*(Continued from p. 63)*

minum Coatings on Iron", by A. Hauttmann, *Stahl und Eisen*, Vol. 51, 1931, p. 65.

3. "Ferrous Alloys Containing from 3 to 20% Aluminum", by K. R. Van Horn, ASM Metals Handbook, 1948, p. 605.

4. "Metallization with Aluminum", by C. R. Draper, *Light Metals*, Vol. 10, March 1947, p. 124.

5. "Aluminum Coatings on Iron and Steel", by A. V. Zeerleder, *Korrosion und Metallschutz*, Vol. 12, 1936, p. 275.

6. "Production and Use of Heat Resisting Aluminum Coatings", by G. Kremer and K. E. Volk, *Stahl und Eisen*, Vol. 66, 1947, p. 250.

*(Continued on p. 130)*

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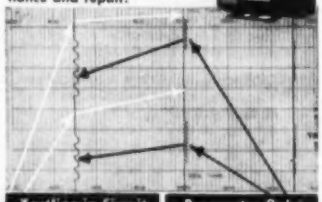


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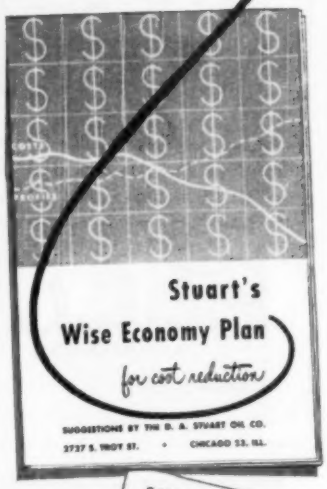

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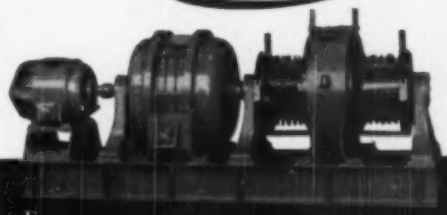

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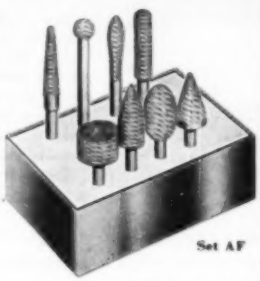

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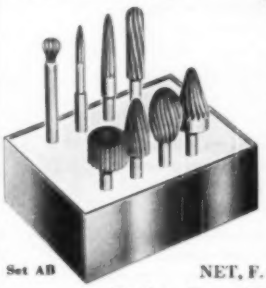

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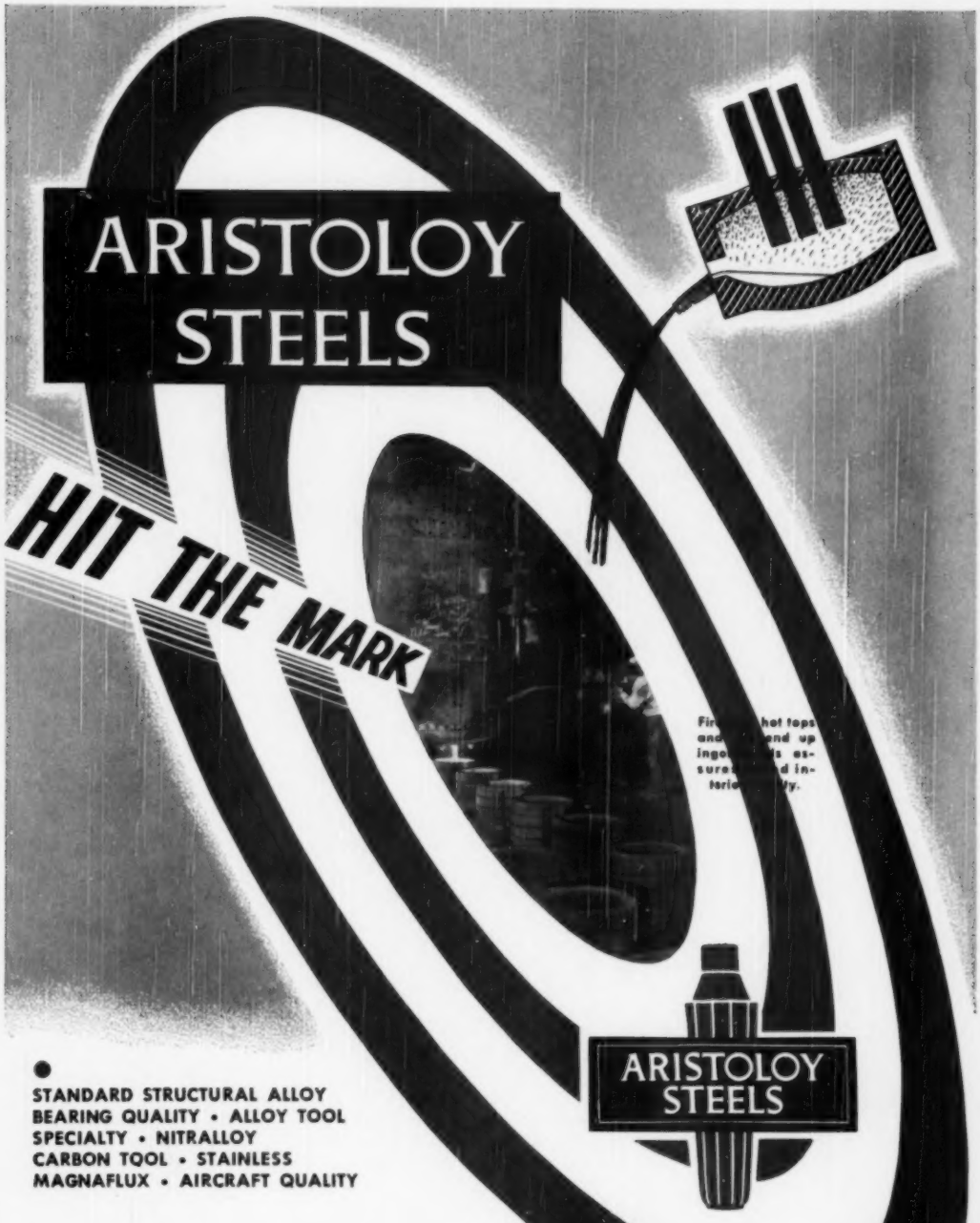


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